PRINCETON STUDIES IN INTERNATIONAL FINANCE
No. 56, September 1985

Real-Exchange-Rate Variability from 1920 to 1926 and 1973 to 1982

Paul De Grauwe
Marc Janssens
and
Hilde Leliaert

INTERNATIONAL FINANCE SECTION
DEPARTMENT OF ECONOMICS
PRINCETON UNIVERSITY

PRINCETON STUDIES IN INTERNATIONAL FINANCE

PRINCETON STUDIES IN INTERNATIONAL FINANCE are published by the International Finance Section of the Department of Economics of Princeton University. While the Section sponsors the Studies, the authors are free to develop their topics as they wish. The Section welcomes the submission of manuscripts for publication in this and its other series, ESSAYS IN INTERNATIONAL FINANCE AND SPECIAL PAPERS IN INTERNATIONAL ECONOMICS. See the Notice to Contributors at the back of this Study.

Paul De Grauwe, one of the authors of this Study, is Professor of Economics at the University of Louvain, Belgium. He has been a visiting professor at the Universities of Michigan and Pennsylvania and at the University of Paris. He has published a number of books, including *Macroeconomic Theory for the Open Economy*, as well as articles on international monetary economics. Marc Janssens was a research associate at the University of Louvain and is now an economic journalist at the Flemish newspaper, *De Standaard.* Hilde Leliaert is a graduate student at the University of Michigan.

PETER B. KENEN, *Director*
International Finance Section

PRINCETON STUDIES IN INTERNATIONAL FINANCE
No. 56, September 1985

Real-Exchange-Rate Variability from 1920 to 1926 and 1973 to 1982

Paul De Grauwe
Marc Janssens
and
Hilde Leliaert

INTERNATIONAL FINANCE SECTION
DEPARTMENT OF ECONOMICS
PRINCETON UNIVERSITY

Library of Congress Cataloging in Publication Data

Grauwe, Paul De.
Real-exchange-rate variability from 1920 to 1926 and 1973 to 1982.

(Princeton studies in international finance, ISSN 0081-8070 ; no. 56 (Sept. 1985))
Bibliography: p.
1. Foreign exchange—History. I. Janssens, Marc. Leliaert, Hilde. III. Title. IV. Series: Princeton studies in international finance ; no. 56.
HG3815.G73 1985 332.4'5'09 85-14308
ISBN 0-88165-228-8 (pbk.)

Printed in the United States of America by Princeton University Press at Princeton, New Jersey.

International Standard Serial Number: 0081-8070
International Standard Book Number: 0-88165-228-8
Library of Congress Catalog Card Number: 85-14308

CONTENTS

1 INTRODUCTION 1

2 REAL-EXCHANGE-RATE VARIABILITY: THE HISTORICAL EVIDENCE 2

3 SPECTRAL ANALYSIS OF REAL EXCHANGE RATES 11

4 REAL-EXCHANGE-RATE VARIABILITY AND INFLATION: THE THEORY 14

5 REAL-EXCHANGE-RATE VARIABILITY AND INFLATION: EMPIRICAL RESULTS 21

6 PURCHASING-POWER PARITY AND HYPERINFLATION 27

7 CONCLUSION 29

APPENDIX A ALTERNATIVE MEASURES OF REAL EXCHANGE RATES 31

APPENDIX B DATA DESCRIPTION 32

APPENDIX C EXCHANGE RATES AND INFLATION 33

APPENDIX D SPECTRAL ANALYSIS OF REAL EXCHANGE RATES 36

REFERENCES 44

LIST OF TABLES

1	Mean and Standard Deviation of Monthly Absolute Changes in Real Exchange Rates, Wholesale Prices	6
2	Standard Deviation of Real Exchange Rates from Sample Mean, Wholesale Prices	7
3	Mean and Standard Deviation of Monthly Absolute Changes in Real Cross Exchange Rates, Wholesale Prices	7
4	Mean and Standard Deviation of Monthly Absolute Changes in the Wholesale-Price Index and the Nominal Exchange Rate	8
5	Correlation between Changes in Price Levels, Nominal Exchange Rates, and Real Exchange Rates	9
6	Mean and Standard Deviation of Monthly Absolute Changes in Nominal Exchange Rates and Stock Prices	10
7	Inflation and Variability in Real Exchange Rates	22
8	Variability in the Real Exchange Rate, Inflation, and Money Growth	23
9	Monetary Shocks and Variability in Real Exchange Rates	24
10	Frenkel's Estimations of Equation (16) for the German Hyperinflation	28
A-1	Mean and Standard Deviation of Monthly Absolute Changes in Real Exchange Rates, Material-Price or Cost-of-Living Index and Consumer-Price Index, 1920s and 1970s	31
A-2	Mean and Standard Deviation of Monthly Absolute Changes in the Material-Price Index and the Consumer-Price Index, 1920s and 1970s	31
D-1	F-Tests for Significance of Linear and Quadratic Trends in the Real Exchange Rate, Early 1920s and 1973-82	37
D-2	F-Tests for Significance of Linear and Quadratic Trends in the Real Exchange Rate, 1973-78 and 1978-82	37
D-3	Standard Deviations of Monthly Real Exchange Rates	38
D-4	Comparison of Peak Frequencies in Two Subperiods of Equal Length, 1920s	39
D-5	Comparison of Peak Frequencies in Two Subperiods of Equal Length, 1970s	40

LIST OF FIGURES

1	Real Franc/Dollar Exchange Rate, France	3
2	Real Mark/Dollar Exchange Rate, Germany	4
3	Real Sterling/Dollar Exchange Rate, United Kingdom	5
4	The Simple Model	17
5	Effect of Transactions Costs on the Working of the Model	19
6	Inflation and Variability in the Real Exchange Rate	23
7	Monetary Shocks and Variability in the Real Exchange Rate	25
8	Hyperinflation and Low Inflation	28
C-1	Exchange Rates and Inflation, France, 1921-30, 1973-82	33
C-2	Exchange Rates and Inflation, Germany, 1914-23, 1973-82	34
C-3	Exchange Rates and Inflation, United Kingdom, 1921-30, 1973-82	35
D-1	Spectrum of Real Exchange Rate, France, 1921-26, 1973-77, 1978-82	41
D-2	Spectrum of Real Exchange Rate, Germany, 1919-23, 1973-77, 1978-82	42
D-3	Spectrum of Real Exchange Rate, United Kingdom, 1921-25, 1973-77, 1978-82	43

1 INTRODUCTION

The exchange-rate movements observed during the 1970s were larger than predicted by most economists. These large exchange-rate movements led in turn to large and sometimes sustained movements in real exchange rates, that is, deviations from purchasing-power parities. Have these recent variations in real exchange rates been larger than those that occurred during other historical episodes of flexible exchange rates? In this Study we analyze this question by comparing the exchange-rate experience of the 1970s with the experience in the first half of the 1920s, when the prevailing exchange-rate regime among the major currencies was similar.

Such a historical study is important because recent economic theorizing about exchange rates has started from a number of stylized facts pertaining to the 1970s. As will be clear from the present Study, however, these stylized facts do not all carry over to other historical periods with different experiences of inflation and monetary policy-making (called, for short, "monetary regimes"). As a result, the models we have now may not be very robust in the face of important changes in the monetary regime. By attempting to broaden the historical horizon to include the 1920s in our sample, and in particular the hyperinflationary German episode, we hope to shed some light on the relationship between the variability of real exchange rates and the monetary regime.

Chapter 2 defines real exchange rates and describes their historical path. Chapter 3 contains a spectral analysis of real exchange rates during 1920-26 and 1973-82. Chapter 4 advances a hypothesis to explain the short-run variability of real exchange rates, and Chapters 5 and 6 present the empirical evidence. The final chapter summarizes the main findings.

This Study was made possible by a grant of the Belgian Ministry of Science (Geconcerteerde Onderzoeksactie GOA 80-85/1). Useful comments by Joshua Aizenman, Jorge de Macedo, Jeffrey Carmichael, Marcus Miller, Richard Marston, and an anonymous referee are gratefully acknowledged.

2 REAL-EXCHANGE-RATE VARIABILITY: THE HISTORICAL EVIDENCE

This chapter presents real exchange rates against the dollar for three major currencies during the 1920s and 1970s: the French franc, the mark, and the pound. The real exchange rate is defined as follows:

$$R_{jk} = S_{jk}(P_j / P_k) \ ,$$

where S_{jk} = index of the price of currency j in units of currency k (the nominal exchange rate)

P_j = general price index for country j

P_k = general price index for country k (using two alternative indices—wholesale and CPI).

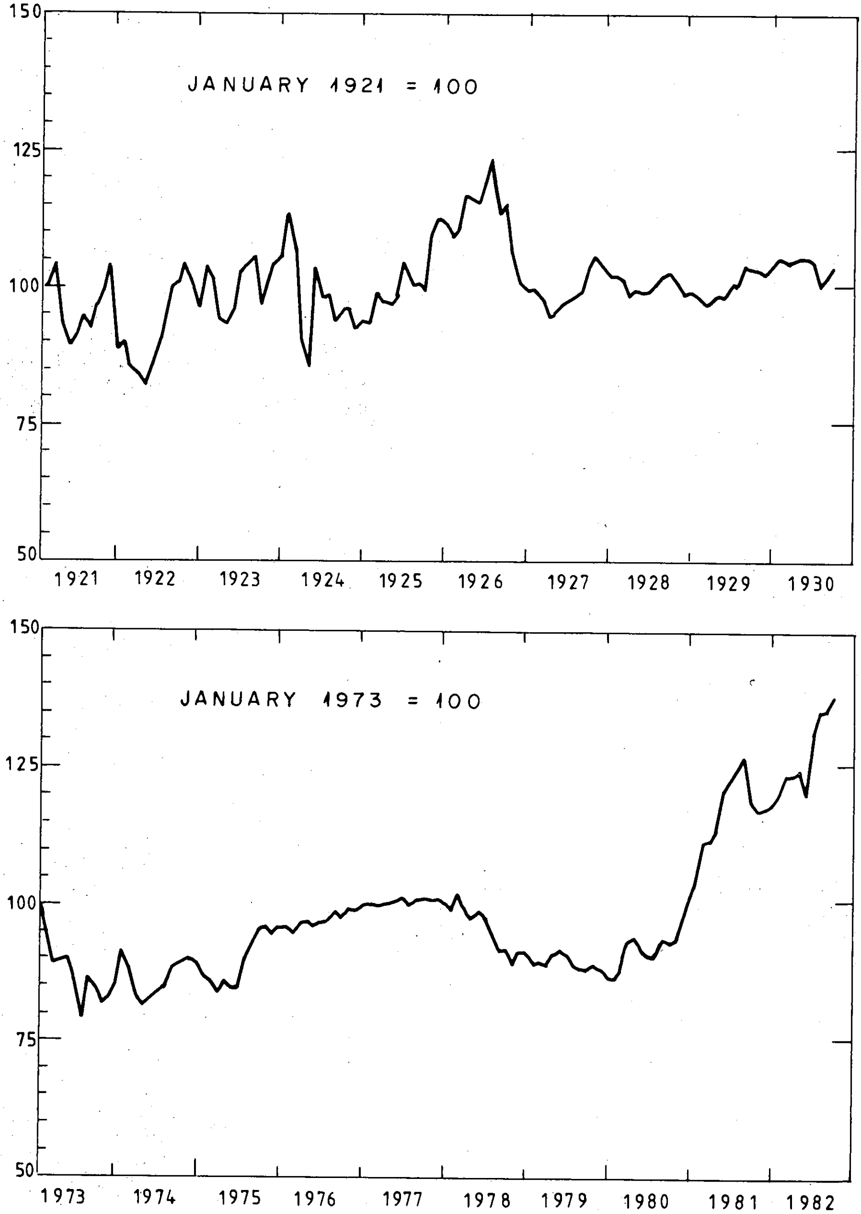
Figures 1 to 3 present the real exchange rates for the two periods, using the wholesale-price index.[1] We concentrate on the first half of the 1920s because from 1925-26 on there was a general return to fixed exchange rates.

From a visual inspection of the series it appears that, in the case of the franc and the mark, the short-run (monthly) variability of the real exchange rate was higher during the 1920s than during the 1970s. During the 1970s, however, the data seem to show more protracted and systematic movements in the real exchange rates, especially in the case of the franc and pound. It is especially noteworthy that after 1975-76 the real exchange rates of the three currencies exhibited trendlike or cyclical movements. Such systematic movements do not seem to have occurred during the 1920s.

To give more precision to the previous observations, several indicators of variability were computed. (For a more detailed discussion of measures of exchange-rate variability, see Kenen, 1979; Kenen and Rodrik, 1984; and Lanyi and Suss, 1982.) As indicators of short-run variability, we selected the mean monthly absolute change in the real exchange rate, its standard deviation, and the range between the maximum and the minimum monthly change (Table 1). We also computed the standard deviation of the real exchange rate around its sample mean (Table 2). This last indicator also measures the long-run variability of the real exchange rate; it will be high when the real exchange rate moves little over periods of a month but tends to wander in one or the other direction over a longer period.

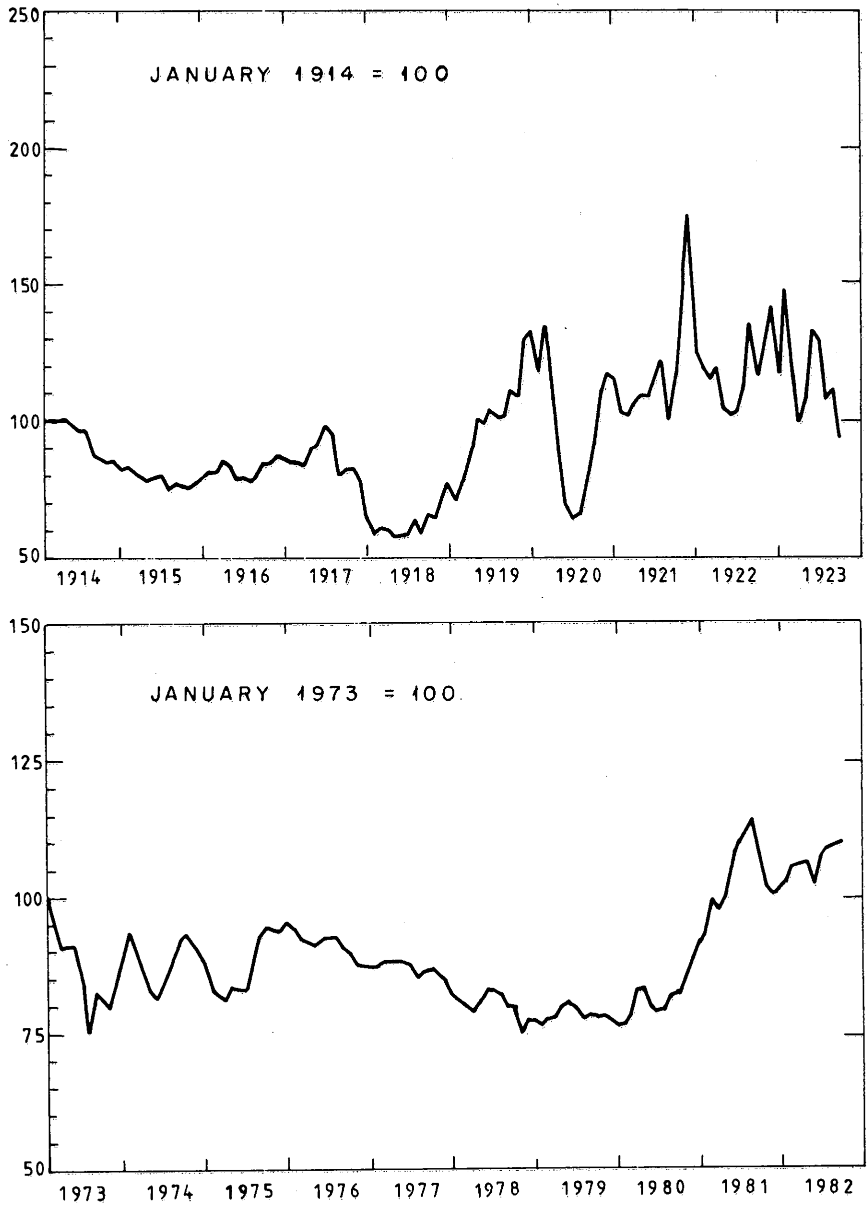
[1] Appendix A presents alternative measures of real exchange rates using the material-price or cost-of-living index for the 1920s and the consumer-price index (CPI) for the 1970s.

FIGURE 1
REAL FRANC/DOLLAR EXCHANGE RATE, FRANCE



SOURCE: See Appendix B.

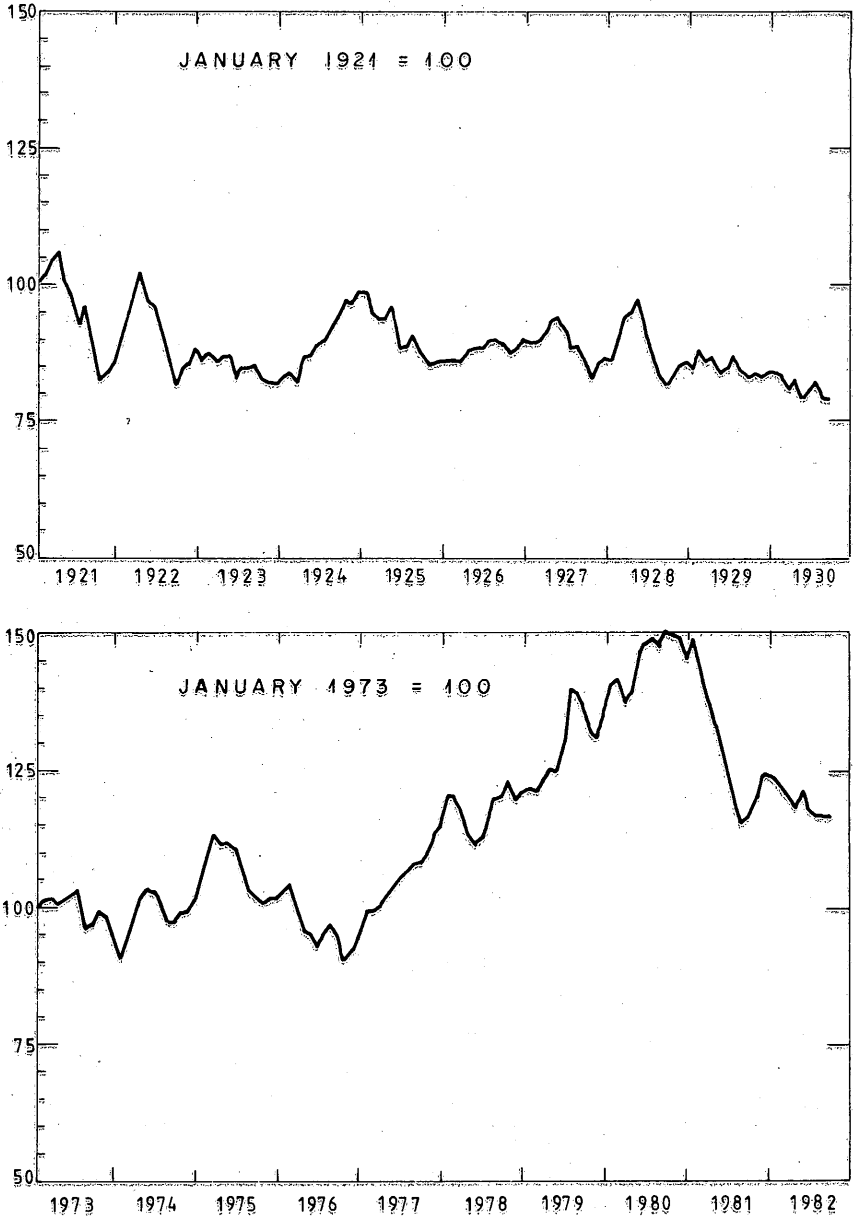
FIGURE 2
REAL MARK/DOLLAR EXCHANGE RATE, GERMANY



SOURCE: See Appendix B.

FIGURE 3

REAL STERLING/DOLLAR EXCHANGE RATE, UNITED KINGDOM



SOURCE: See Appendix B.

TABLE 1

MEAN AND STANDARD DEVIATION OF MONTHLY ABSOLUTE CHANGES IN REAL EXCHANGE RATES, WHOLESALE PRICES
(*in percent*)

	Mean Absolute Change	*Standard Deviation*	*Range*[a]
1920s:			
franc/dollar (1921-26)	4.2	3.7	35.9
mark/dollar (1919-23)	11.0	8.0	31.0
sterling/dollar (1921-25)	2.7	2.0	13.4
1970s:			
franc/dollar (1973-82)	2.0	2.0	17.0
mark/dollar (1973-82)	2.3	2.1	21.0
sterling/dollar (1973-82)	2.1	1.5	15.0

SOURCE: See Appendix B.
[a] The difference between the maximum and minimum monthly change.

The following generalizations can be drawn from the evidence in Table 1. First, the short-run (monthly) variability of real exchange rates was larger during the 1920s than during the 1970s for the franc/dollar and mark/dollar rates. The variability of the sterling/dollar rate was of the same order of magnitude in the two periods. The difference in the degree of variability is most pronounced in the case of the mark/dollar rate. During the German hyperinflation it was not uncommon for the real exchange rate to change 50 to 100 percent in a few months' time. This statistical evidence is in accordance with the anecdotal evidence about this period, indicating how large deviations from purchasing-power parity (PPP) led to large profit opportunities (see Bresciani-Turroni, 1937, and de Jonge, 1979; see also Aliber, 1980). But it seems to contradict the empirical study by Frenkel (1978), which concluded that the PPP relationship was very tight during the German hyperinflation. When we come to this problem we will indicate how Frenkel's results can be interpreted in the light of our own results.

The evidence in Table 2 confirms the visual impression given by Figures 1 through 3 that real exchange rates exhibited longer movements during the 1970s than during the 1920s. Although real exchange rates tended to fluctuate less in the short run during the 1970s, there was a substantial amount of variation over longer runs of several years. In other words, deviations from PPP appear to have been more protracted. We come back to this issue in Chapter 3, where we subject the data to spectral analysis.

TABLE 2

STANDARD DEVIATION OF REAL EXCHANGE RATES FROM SAMPLE MEAN, WHOLESALE PRICES
(in percent)

	Standard Deviation
1920s:	
franc/dollar (1921-26)	8.8
mark/dollar (1919-23)	20.2
sterling/dollar (1921-25)	7.0
1970s:	
franc/dollar (1973-82)	14.6
mark/dollar (1973-82)	11.1
sterling/dollar (1973-82)	29.2

SOURCE: See Appendix B.

In this Study we will be concerned mostly with exchange rates relative to the dollar. It is important, however, to know how cross rates have changed. The information given in Table 3 should be compared with that in Table 1. It appears that during the 1920s exchange rates involving the mark (which experienced hyperinflation) were much more volatile than other exchange rates (e.g., sterling/dollar, franc/sterling, and franc/dollar). Table 3 also confirms that during the 1970s the real exchange rates of the

TABLE 3

MEAN AND STANDARD DEVIATION OF MONTHLY ABSOLUTE CHANGES IN REAL CROSS EXCHANGE RATES, WHOLESALE PRICES
(in percent)

	Mean Absolute Change	*Standard Deviation*	*Range*
1920s:			
franc/sterling (1921-25)	4.1	4.0	37.8
mark/franc (1919-23)	14.8	10.5	77.8
mark/sterling (1919-23)	13.4	8.9	60.1
1970s:			
franc/sterling (1973-82)	1.9	1.5	12.5
mark/franc (1973-82)	1.1	1.1	8.9
mark/sterling (1973-82)	1.9	1.7	11.1

SOURCE: See Appendix B.

European currencies against each other were much less volatile than during the 1920s.

For a better understanding of the nature of the short-term variability in real exchange rates, it is important to relate it to the volatility of other variables. We do this first by analyzing the variability of nominal exchange rates and of inflation rates (which together define the variability of real exchange rates), and second by relating exchange-rate variability to the variability of stock prices.

How are variations in nominal and real exchange rates related? Tables 4 and 5 provide some evidence. Table 4 shows the means and standard deviations of monthly changes in prices and nominal exchange rates. Table 5 presents the correlation matrix of changes in price levels, nominal exchange

TABLE 4

MEAN AND STANDARD DEVIATION OF MONTHLY ABSOLUTE CHANGES IN THE WHOLESALE-PRICE INDEX AND THE NOMINAL EXCHANGE RATE

(in percent)

	Mean Absolute Change	*Standard Deviation*	*Range*
	Wholesale Prices		
1920s:			
France	3.2	3.0	23.0
Germany	47.0	105.0	569.0
U.K.	2.5	2.4	17.9
U.S.	1.2	1.2	11.7
1970s:			
France	1.0	1.0	7.4
Germany	0.5	0.5	3.2
U.K.	1.2	0.7	4.3
U.S.	0.9	0.8	7.2
	Nominal Exchange Rates		
1920s:			
franc/dollar	6.0	5.3	26.0
mark/dollar	51.7	100.7	554.5
sterling/dollar	1.4	1.3	10.3
1970s:			
franc/dollar	2.1	1.9	15.5
mark/dollar	2.2	1.9	16.7
sterling/dollar	1.9	1.4	12.5

SOURCE: See Appendix B. See also Appendix C for the graphs of inflation and exchange rates.

TABLE 5

CORRELATION BETWEEN CHANGES IN THE PRICE LEVELS (ΔP), NOMINAL EXCHANGE RATES (ΔS), AND REAL EXCHANGE RATES (ΔR)

	France			*Germany*			*United Kingdom*		
	ΔP	ΔS	ΔR	ΔP	ΔS	ΔR	ΔP	ΔS	ΔR
1920s:									
ΔP	1.00			1.00			1.00		
ΔS	0.54	1.00		0.99	1.00		0.18	1.00	
ΔR	0.15	0.80	1.00	0.10	0.13	1.00	0.65	0.25	1.00
1970s:									
ΔP	1.00			1.00			1.00		
ΔS	0.31	1.00		0.27	1.00		0.04	1.00	
ΔR	0.27	0.82	1.00	0.29	0.91	1.00	0.33	0.76	1.00

SOURCE: See Appendix B.

rates, and real exchange rates. The simple correlation gives an indication of the extent to which the variations in the series are related. (Appendix C contains the graphs of these three variables.)

The data in these two tables lend themselves to the following interpretation. First, the short-term variability of the wholesale-price changes was generally higher during the 1920s in the four countries analyzed here. Germany, of course, provides an extreme example of high price variability. The variability in the nominal exchange rates tended to be higher in the 1920s for the mark/dollar rate and to a lesser degree for the franc/dollar rate. Second, the pattern of correlation between the changes in these three variables (inflation, real exchange rates, and nominal exchange rates) was substantially different in the two periods. During the 1970s, one observes high correlations between real and nominal exchange-rate changes. These correlations are generally lower during the 1920s. On the other hand, the correlation between changes in prices and nominal exchange rates tended to be higher during the 1920s than during the 1970s.

This evidence supports the idea that prices tended to be stickier during the 1970s than the 1920s. It also explains why the sticky-price models of exchange-rate determination have become popular during the 1970s. We will return to this problem in Chapter 4, where we use a theoretical framework linking short-term price stickiness to the nature of stochastic shocks in the economy.

In this historical comparison it is useful to compare exchange-rate variability with the variability of stock prices. It is now generally recognized that, in the short run, nominal exchange rates behave like stock prices, as they adjust to maintain stock equilibrium in domestic and foreign asset markets. Table 6 compares the short-term variability of exchange rates and of stock prices during the two periods. The most striking result is that during the 1970s the variability of exchange rates was lower than the variability of stock prices, whereas the opposite was true for France and Germany during the 1920s.[2] During that period, exchange rates were substantially more variable than stock prices in these two countries.

TABLE 6

MEAN AND STANDARD DEVIATION OF MONTHLY ABSOLUTE CHANGES IN NOMINAL EXCHANGE RATES AND STOCK PRICES
(in percent)

	Mean		*Standard Deviation*	
	Exchange Rate	*Stock Price*	*Exchange Rate*	*Stock Price*
1920s:				
France	6.2	3.5	5.3	2.8
Germany	51.7	13.8	100.7	12.5
U.K.	1.4	2.7	1.3	2.4
1970s:				
France	2.1	4.9	1.9	4.8
Germany	2.2	2.6	1.9	2.4
U.K.	1.9	4.6	1.4	4.8

SOURCE: See Appendix B.

[2] This is in accordance with Levich (1981).

3 SPECTRAL ANALYSIS OF REAL EXCHANGE RATES

The statistical analysis of changes in real exchange rates can be refined by using more powerful methods. In this chapter, the data are subjected to spectral analysis.

Spectral analysis is a statistical technique that makes it possible to decompose a time series into cycles of different frequencies. As a result, we obtain information about the extent to which the total variability of a series is due to cycles of different frequencies. For example, a time series of twenty years may exhibit strong seasonal variability around a business cycle of five years. Spectral analysis will tell us how much of the total change is due to the business cycle (a low-frequency cycle that repeats itself four times) and how much to seasonal movement (a high-frequency cycle that repeats itself twenty times).

Spectral analysis accomplishes this decomposition by attaching numerical values (the spectra) to these different cycles. A high spectrum for a cycle of particular frequency means that this cycle is important in explaining the total variability of the time series. In the example of the previous paragraph, the spectra of the cycles that occur four times and twenty times will be high. The others will be low.

To apply spectral analysis one must be sure that the time series is stationary. Stationarity here involves three different things. First, the series must be stationary in the mean: the mean must not change in a systematic way over the sample period. For all practical purposes, this statement implies that there should be no trend in the data. If there is, the series must be detrended. Second, the variance of the series should not change systematically during the sample period: the degree of variability should be constant. Third, the degree of covariation of observations at different time intervals should not change during the sample period. This is called "covariance stationarity."[1]

Are the time series stationary in these three senses? Appendix D describes the tests used to answer this question. Here we discuss the main results.

During the 1970s, the levels of all real exchange rates are nonstationary in the mean: they exhibit clear trendlike behavior. This evidence confirms

[1] Thus, if during the sample period the autocorrelation of a time series increases, it is covariance nonstationary.

the findings described in Chapter 2 that systematic changes occurred in the real exchange rates of France, Germany, and the United Kingdom. The evidence for the 1920s is mixed. The franc/dollar rate is nonstationary in the mean; the sterling/dollar rate is on the borderline of being nonstationary; and the mark/dollar rates does not exhibit a clear trend.

Tests of stationarity in the variance revealed little evidence that real exchange rates were nonstationary in the variance during either the 1920s or the 1970s. Covariance nonstationarity was detected in the pound/dollar rate during the 1920s and in the franc/dollar and mark/dollar rates during the 1970s. Therefore, some caution should be exercised in the interpretation of the spectral analysis of these two series.

The next step in the analysis consists of computing the spectra of the levels of real exchange rates. All series are expressed as differences from the sample mean. When a series was found to be nonstationary in the mean, it was adjusted for trend.

The spectra of the different series are shown in Appendix D (Figures D-1 to D-3). In order to make the 1970s and the 1920s more comparable, the period 1973-82 was split into two equal subperiods, so that the length of these periods matches the period of the 1920s analyzed here.[2]

. The main conclusions from this spectral analysis are the following: During the 1920s, spectra at frequencies higher than zero are significant. This is especially true for Germany and France. For Germany, cycles of 20 months were important during the hyperinflation. For France, larger cycles of 36 months are found. Similar results are obtained for the first part of the floating-rate period, from 1973 to 1978. Cycles of 20 to 30 months are significant for all three exchange rates, but the amplitude of these cycles is much lower than in the 1920s. A significant change in the nature of variability occurs from 1978 on (i.e., in the second subperiod). Short-term cycles almost completely disappear. The exchange-rate series are dominated by longer-run movements (i.e., low-frequency cycles). In addition, the spectra tend to be higher in the second subperiod than in the first.

Summing up these results from the spectral analysis, one can state that during the 1920s a substantial part of the total variability in real exchange rates was accounted for by short-term (20- to 30-month) cycles. This was much less the case during the 1973-82 period, and especially during the

[2] The spectra were computed after smoothing by using a Barlett filter. The use of a Daniel filter did not change the results in any significant way.

second half of that period, when changes in real exchange rates were dominated by long-run movements (low-frequency cycles).

The statistical evidence of this and the previous chapter demonstrates that in the floating-rate period of the 1920s the exchange markets for the mark and French franc were considerably more turbulent than in the 1970s. This led to larger short-term variations in the real exchange rates for those currencies. In addition, the changes in the nominal exchange rates were more highly correlated with price changes than in the 1970s. In contrast, during the 1970s there was a higher correlation between changes in real exchange rates and changes in nominal exchange rates.[3] This empirical phenomenon has been important in the development of sticky-price models of exchange-rate determination.

A second element in this broad statistical picture is that real exchange rates tended to change in a more permanent way during the 1970s. There are several possible explanations. One relies on the idea that during the 1970s and early 1980s large real shocks (such as the oil shocks) occurred that necessitated permanent changes in real exchange rates (see Frenkel, 1981). Another interpretation of the sustained changes in real exchange rates, especially since 1979, is that macroeconomic policies (both monetary and budgetary) have been seriously out of line across major industrial countries, producing a set of misaligned real exchange rates (see Williamson, 1983, and Emminger, 1983).

The evidence provided here does not allow us to discriminate between these two competing hypotheses. The low-frequency band in which the spectra of real exchange rates are concentrated is wide enough to accommodate both explanations. We will therefore not deal with these long-run changes in real exchange rates, but instead attempt to explain their short-run variability.[4]

[3] We also computed the cross-spectra between real and nominal exchange rates (not reported here). These cross-spectra allowed us to decompose the correlation between two different series into correlations of the cycles with different frequencies. However, we detected significant differences between the 1920s and the 1970s only for France, where we found substantially more correlation between the real and nominal exchange rates in the 3- to 4-month cycle during the 1970s.

[4] For a thorough discussion of long-run changes, see Katseli (1979). For a recent empirical analysis of the structural factors affecting long-run deviations from PPP, see Kravis and Lipsey (1983). See also Officer (1982).

4 REAL-EXCHANGE-RATE VARIABILITY AND INFLATION: THE THEORY

In the preceding chapters we observed substantial differences in the variability of real exchange rates across countries and historical episodes. In this chapter we attempt to explain these differences. The hypothesis formulated here is that the variability of real exchange rates is positively related to the variability of monetary disturbances.

In order to give more precision to this hypothesis, we use a simple monetary model of exchange-rate determination. Our discussion draws heavily on Aizenman (1984), who provides a model endogenizing short-term movements of real exchange rates. The model is based on two strands of economic thinking about exchange rates. One is the sticky-price model (Dornbusch, 1976). The other is the "news" model of exchange-rate determination (Mussa, 1976, and Frenkel, 1981). The model as amended here allows us to show how the size of fluctuations in real exchange rates and the degree of price stickiness are related to the nature of monetary disturbances.

From the outset we want to stress that, although the model pays most attention to the link between monetary disturbances and real-exchange-rate changes, we do not consider monetary factors to be the sole causes of real-exchange-rate changes. As the previous chapter has illustrated, there are certainly other factors, for example relative price shocks, that contributed to real-exchange-rate movements during the 1970s. The model developed here has a more limited purpose. It tries to explain why the short-run variability of real exchange rates has been so different across countries, despite similar relative price shocks.

Consider a small open economy in a world of one traded good with perfect capital mobility. Money-market equilibrium obtains when the demand for money (m_d) equals the supply (m_s). The demand function for money is specified in log-linear form:

$$m_{dt} = p_t + y_t - \alpha r_t \, , \qquad (1)$$

where m_{dt} is the log of the demand for money, p_t is the log of the domestic price of the traded good, y_t is the log of the output level, and r_t is the domestic interest rate, all in period t. For the sake of convenience, we have assumed that the income elasticity of the demand for money is equal to one. Money-market equilibrium implies

$$m_{dt} = m_{st} = m_t \ , \tag{2}$$

where m_t is the log of the actual money stock, so

$$m_t = p_t + y_t - \alpha r_t \ . \tag{3}$$

The domestic interest rate is assumed to be determined by uncovered interest parity:

$$r_t = r_{ft} + E_t\, e_{t+1}\text{-}e_t \ , \tag{4}$$

where r_{ft} is the foreign interest rate, $E_t\, e_{t+1}$ is the expectation in period t of the log of the next period's exchange rate, and e_t is the log of the actual exchange rate in period t. Note that we disregard here the existence of risk premia.[1]

We now introduce price stickiness. To start, we merely assume price stickiness; subsequently, the degree of price stickiness is made endogenous by explicitly specifying the nature of transactions costs in the goods market. Suppose that the domestic price, p_t, is set at the end of period $t-1$ on the basis of current expectations about the exchange rate and foreign price level in period t. Taking PPP as the point of departure,

$$p_t = E_{t-1}(p_{ft} + e_t). \tag{5}$$

The implicit assumption underlying this price-setting behavior is that transactions costs are high enough to permit small deviations from PPP and thus prevent a flow of goods from (or to) the outside world that would equalize the domestic and foreign prices of the traded good during period t. We will relax this assumption later.

Substituting (5) into (3) and (4) into (3) yields an expression for the exchange rate:

$$e_t = (1/\alpha)[m_t - y_t + \alpha r_{ft}] - (1/\alpha)[E_{t-1}(p_t + e_t)] + E_t\, e_{t+1} \ . \tag{6}$$

[1] For empirical evidence on risk premia, see Levich (1985) and Frankel (1984).

We can now contrast the exchange rate obtained in (6) with the exchange rate obtained assuming complete price flexibility. The latter implies that

$$\bar{p}_t = p_{ft} + \bar{e}_t \,. \tag{7}$$

The domestic price level will adjust instantaneously to its PPP level. Note that we use the notation $\bar{e}_t$ and $\bar{p}_t$ to indicate that this is the solution under price flexibility. Substituting (7) into (3),

$$\bar{e}_t = (1/\alpha)[m_t - y_t + \alpha r_{ft}] - (1/\alpha)[p_{ft} + \bar{e}_t] + E_t \bar{e}_{t+1} \,. \tag{8}$$

Subtracting (8) from (6) yields

$$\begin{aligned} e_t - \bar{e}_t = {} & (1/\alpha)[\bar{e}_t + p_{ft} - E_{t-1}(p_{ft} + e_t)] \\ & + E_t e_{t+1} - E_t \bar{e}_{t+1} \,. \end{aligned} \tag{9}$$

If we assume that expectations are set rationally, it follows that[2]

$$E_t e_{t+1} = E_t \bar{e}_{t+1} \,, \tag{10}$$

so that (9) reduces to

$$e_t - \bar{e}_t = (1/\alpha)[\bar{e}_t + p_{ft} - E_{t-1}(\bar{e}_t + p_{ft})] \tag{11}$$

or

$$e_t - \bar{e}_t = (1/\alpha)[\bar{p}_t - E_{t-1}\bar{p}_t] \,. \tag{12}$$

Equation (12) tells us that the exchange rate under the pre-set-price rule will deviate from the exchange rate under price flexibility to the extent that economic agents make errors in forecasting the price level (i.e., the world price and the exchange rate).

Using (5) and (7), we can rewrite equation (12) to define the log of the real exchange rate as deviation from PPP:

$$\theta_t \equiv e_t + p_{ft} - p_t = (1 + 1/\alpha)[\bar{p}_t - E_{t-1} \bar{p}_t] \,. \tag{13}$$

[2] See Aizenman (1984, p. 6). This result follows from the fact that future "innovations" in the exogenous variables (e.g., the foreign price level) are not part of the current information set. Therefore, under the two price regimes, rational economic agents expect the same future price level and future exchange rate.

The deviations from PPP (θ) can also be expressed as a function of the unanticipated disturbances in the exogenous variables of the model. One then obtains

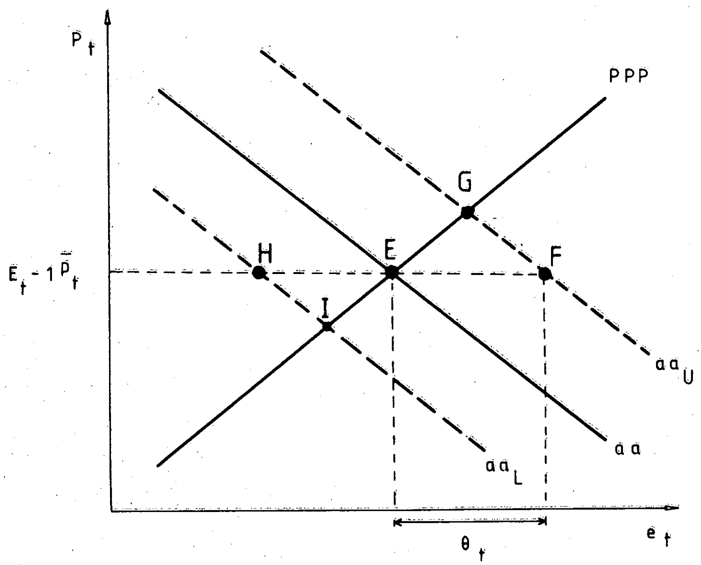
$$\theta_t = (1/\alpha)[(m_t - E_{t-1}m_t) - (y_t - E_{t-1}y_t)] + (p_{ft} - E_{t-1}\, p_{ft}) + (r_{ft} - E_{t-1}r_{ft})\,. \tag{14}$$

Equations (13) and (14) imply that "surprises" in money, output, foreign prices, and foreign interest rates, by leading to unanticipated price disturbances, lead to deviations from PPP.

The model discussed here has a simple graphical representation (adapted from Dornbusch, 1976). The *aa* curve in Figure 4 is the asset-market equilibrium curve represented by equations (3) and (4). It is given by the foreign interest rate and expectations prevailing in period *t* about the future exchange rate. The PPP curve represents equation (7).

We can now use the model to analyze the effects of exogenous disturbances and show how the sizes of disturbances affect the workings of the model. We consider only stochastic (unanticipated) disturbances and as-

FIGURE 4
THE SIMPLE MODEL



sume that they originate in the asset markets. In fact, we restrict the analysis to the effects of monetary disturbances. As equation (14) makes clear, monetary disturbances are not the only source of deviations from PPP, but the effects of nonmonetary disturbances will not be analyzed here.

In Figure 4, these monetary disturbances produce random movements of the *aa* curve. We represent this by a band set by aa_U and aa_L within which the *aa* curve can shift randomly. The stronger these disturbances, the wider is the band. In the flexible-price version of the model, the equilibrium will fluctuate between the points *I* and *G* on the PPP curve. Thus, the real exchange rate does not change and the correlation between the nominal exchange rate and the price level is perfect.

In the sticky-price version of the model, where the price level is pre-set at $E_{t-1}\tilde{p}_t$, the nominal and real exchange rates will fluctuate between the limits set by points *H* and *F*, and the fluctuations will be perfectly correlated. To give an example, suppose that an unanticipated monetary disturbance has shifted the *aa* curve in period *t* to aa_U. As the price level cannot change in period *t*, the short-term equilibrium point is *F*. (The equilibrium point under price flexibility is at *G*.) The deviation from PPP is measured by the distance *EF*. When the underlying stochastic disturbances increase, the band set by aa_L and aa_U increases so that the short-term deviations from PPP also increase.

The next step in the analysis is to make the nature of the transactions costs explicit. As these explain price stickiness, we will then be able to make the degree of price stickiness endogenous. It will be assumed here that transactions costs are a fixed proportion of the price[3] originating from transporting goods across borders. Thus, we assume here that there is no transactions cost involved in trading goods in the domestic market. The transactions costs per unit is *C*. We then have the following pricing rule:

$$\begin{aligned} &\text{If } |\theta_t| < C \rightarrow p_t = E_{t-1}(e_t + p_{ft}) \,. \\ &\text{If } |\theta_t| \geqslant C \rightarrow p_t = p_{ft} + \tilde{e}_t \pm C \,. \end{aligned} \tag{15}$$

Equation (15) says that if the ex ante deviation from PPP (θ_t) is smaller than the cost of transporting goods (*C*), the price of the domestic good is not influenced by $p_f + e$ (i.e., it will not be profitable to ship goods across borders during period *t* in order to profit from a differential between the domestic and foreign price). In this case, the price is pre-set at its expected

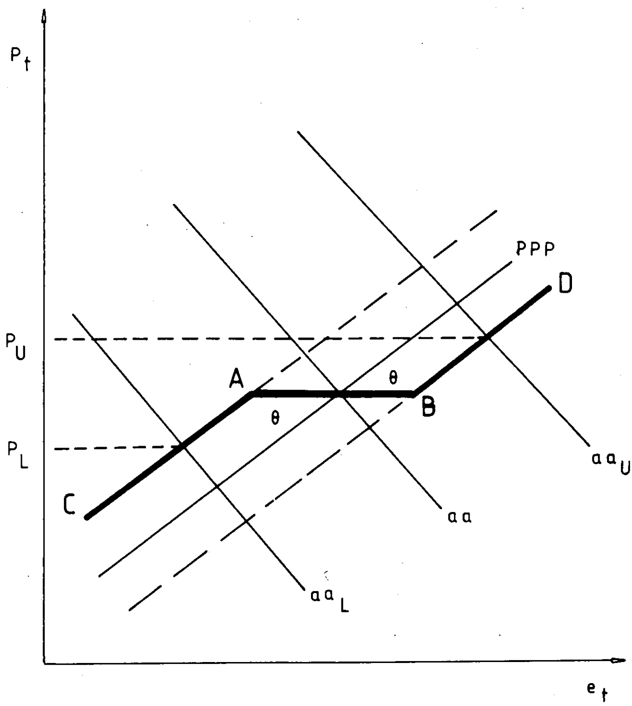
[3] Aizenman (1984) analyzes transactions costs of the lump-sum variety.

PPP level. If, however, the ex ante deviation from PPP exceeds transport costs, goods arbitrage will be undertaken during period t because it is profitable. If $p_t > p_{ft} + e_t + C$, the foreign good will be imported, forcing p_t to equal $p_{ft} + \bar{e}_t + C$; if $p_t < p_{ft} + e_t - C$, the domestic good will be exported, forcing p_t to equal $p_{ft} + \bar{e}_t - C$.

The effect on the working of the model of transactions costs as specified in equation (15) is represented in Figure 5. The existence of transactions costs now introduces a band around the PPP curve within which price stickiness will occur.

It can easily be shown that the degree of price stickiness depends on the size of the stochastic disturbances affecting the aa curve. If these are small compared with the transactions-cost band, prices will be sticky in the short run. If the disturbances increase in size (as represented in Figure 5 by the band between aa_L and aa_U), prices become flexible. The maximum amount

FIGURE 5
EFFECT OF TRANSACTIONS COSTS ON THE WORKING OF THE MODEL



of deviation from PPP is given by θ. The price level will fluctuate between p_U and p_L. Thus, we conclude that as the size of stochastic disturbances underlying the model tends to increase, short-term deviations from PPP first tend to increase. These deviations from PPP are limited, however, when the transactions band around PPP is reached. We obtain a nonlinear relationship between the size of unanticipated monetary shocks and changes in the real exchange rate. When the size of the unanticipated monetary disturbance increases, the size of real-exchange-rate changes first increases but then tends to level off.

A nonlinear relationship also exists between unanticipated price disturbances and real exchange rates. As can be seen from Figure 5, when these disturbances are low we observe points on the flat segment (*AB*) of the crooked curve (*CABD*). As a result, there will be a zero correlation between the price level and the nominal exchange rate, so that there will be a perfect correlation between the nominal and the real exchange rate. When the underlying price disturbances increase, we will start observing points on the upward-sloping parts of *CABD*. This will lead to an increased positive correlation between the price level and the nominal exchange rate, which will reduce the correlation between the nominal and the real exchange rate.

The theoretical model discussed here also allows us to analyze the importance of structural factors, such as the openness of the economy and the proximity to foreign markets, for movements of the real exchange rate.

In geographically small economies that are close to foreign markets, the cost of shipping goods across borders will generally be lower than in large or relatively isolated economies. Therefore, in the former the transactions-cost band around the PPP curve will be smaller than in the latter. As a result, the maximum deviation from PPP will be smaller in the small economies than in the large ones. This difference, however, will become apparent only when the size of the monetary disturbance is large enough to produce changes in the real exchange rate that hit the ceiling imposed by the transactions-cost band around PPP.

Before discussing the empirical results, it is important to stress that, because the model involves several assumptions, we will be testing a joint hypothesis. In particular, we have assumed (a) that PPP will hold in the absence of short-run price rigidity, (b) that expectations are formed in the belief that PPP will hold, and (c) that prices set on the basis of these expectations cannot be revised immediately, which means that there will be short-run deviations from PPP. It should be kept in mind that in testing the model we are constraining these hypotheses to be jointly true.

5 REAL-EXCHANGE-RATE VARIABILITY AND INFLATION: EMPIRICAL RESULTS

In order to test the theory developed in the previous chapter using cross-section data, we now increase our sample of countries and periods by adding some high-inflation countries during the 1970s (Brazil, Argentina, Chile, and Israel). There is no attempt to analyze the empirical importance of structural factors such as openness and proximity to foreign markets in order to explain variations in real exchange rates. To do so one would need a much larger sample of countries experiencing different monetary regimes. This omission of structural variables may bias the results if the variables omitted are correlated with the monetary disturbances.

The theory presented in Chapter 4 predicts, first, that with increasing unanticipated inflation real exchange rates will change in a nonlinear way. Second, it predicts that since unanticipated monetary shocks lead to price disturbances, there will be a similar nonlinear relationship between the degree of variability in real exchange rates and the size of monetary disturbances.

Note that our theoretical model also predicts that nonmonetary disturbances cause deviations from PPP. These nonmonetary shocks, however, are outside the scope of the present Study.

Some of the countries in the sample (France, Germany, the United Kingdom) cannot be considered small, but the theoretical model uses the small-country assumption. Can we, then, apply the model to these countries? Smallness in the theoretical model implies that the foreign-price variable is exogenous. In the empirical work presented here, each country is compared with the United States. Thus, our implicit assumption is that the U.S. rate of inflation is exogenous for all these countries. We assume here that this is true at least as a first approximation.

To see whether the data are consistent with the predictions of the model, we compared short-term changes in real exchange rates first with the size of unanticipated inflation and second with the size of unanticipated monetary disturbances. Because we use cross-section data, we cannot rely on time-series analysis to generate series of unanticipated inflation rates and unanticipated monetary shocks. We therefore selected the standard deviation of monthly inflation rates as a proxy for the size of a country's unanticipated inflation rates during a given period. Similarly, we selected the standard deviation of the monthly changes in the money stock (M2) as a proxy for unanticipated changes in the money stock. The rationale for this procedure is that when one country exhibits a higher standard deviation of monthly inflation rates and money-stock growth rates than another country, we expect inflation and money-growth "surprises" to be larger in the former than in the latter.

Table 7 presents the standard deviation of monthly inflation rates and the mean monthly absolute change in the real exchange rates of the countries in our sample during different periods. We added the mean monthly inflation rate to demonstrate the very high correlation between the levels and variability of inflation rates (correlation coefficient = 0.99). The period of the German inflation was divided into two subperiods, one from 1919 to 1921, when the average inflation rate was relatively low, the other from 1922 to 1923, when inflation took on "hyper" proportions.

TABLE 7

INFLATION AND VARIABILITY IN REAL EXCHANGE RATES
(in percent)

	Mean Monthly Inflation Rate	*Standard Deviation of Monthly Inflation Rate*	*Mean Monthly Change in Real Exchange Rate*
Germany (1922-23)	102.4	150.3	11.7
Argentina (1975-76)	19.4	12.0	11.8
Chile (1973-74)	18.7	24.0	10.8
Germany (1919-21)	9.6	12.4	10.7
Argentina (1980-82)	9.3	5.5	9.2
Israel (1977-81)	5.4	2.8	1.9
Brazil (1973-82)	3.7	2.0	6.1
France (1921-26)	3.2	4.3	5.6
U.K. (1920-25)	2.5	3.4	2.7
U.K. (1973-82)	1.2	0.7	2.6
France (1973-82)	1.0	1.2	2.8
Germany (1973-82)	0.5	0.5	2.3

SOURCE: See Appendix B.

The scatter diagram in Figure 6 relates the variations in the real exchange rate to the standard deviation of the inflation rate. A logistic curve fitted these data best. This curve is defined by

$$y = c + e^{a - b/x},$$

where a, b, and c are coefficients and e is the base of the system of natural logarithms. In this case, the dependent variable, y, is represented by the mean absolute change in the monthly real exchange rate. The variable x is represented by the standard deviation of the monthly inflation rate. The coefficients, t-statistics, and standard error of the regression are shown in the first row of Table 8. The fit is relatively tight with highly significant coefficients.

FIGURE 6

INFLATION AND VARIABILITY IN THE REAL EXCHANGE RATE

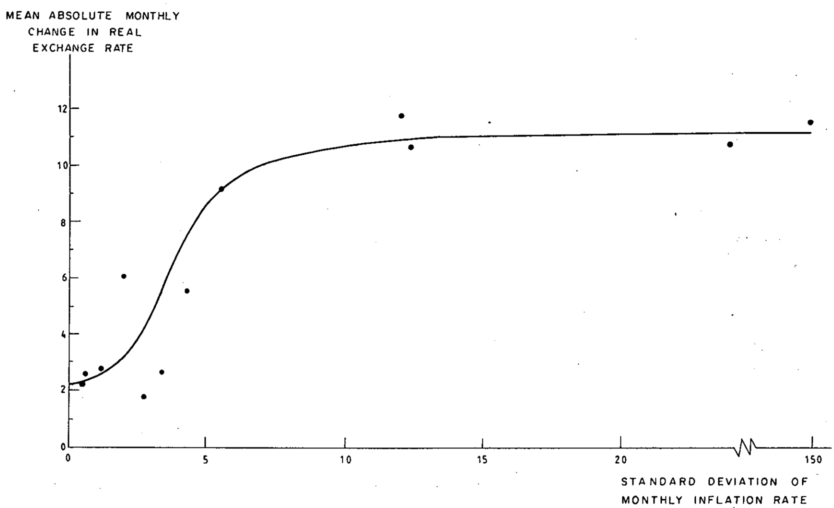


TABLE 8

VARIABILITY IN THE REAL EXCHANGE RATE, INFLATION, AND MONEY GROWTH

Variability in	*c*	*a*	*b*	*SER*
Inflation	2.41 (2.22)	2.41 (15.70)	5.56 (2.70)	1.87
Money growth	1.59 (0.38)	2.33 (6.14)	2.52 (0.94)	3.32

NOTES: In both cases, the dependent variable is the mean absolute change in the monthly real exchange rate. In the first equation, the independent variable is the standard deviation of the monthly inflation rate; in the second, it is the standard deviation of the monthly growth rate of the money stock (M2).

SER = standard error of regression.

Table 9 presents similar information about the relationship between variability in the growth of the money stock and in the real exchange rate. There, too, a logistic curve fitted the data best. We observe a similar nonlinear relationship between these two variables. This relationship is less tight, however, than between variability in inflation and in the real exchange rate (compare Figures 7 and 6 and the estimated nonlinear equations in Table 8).

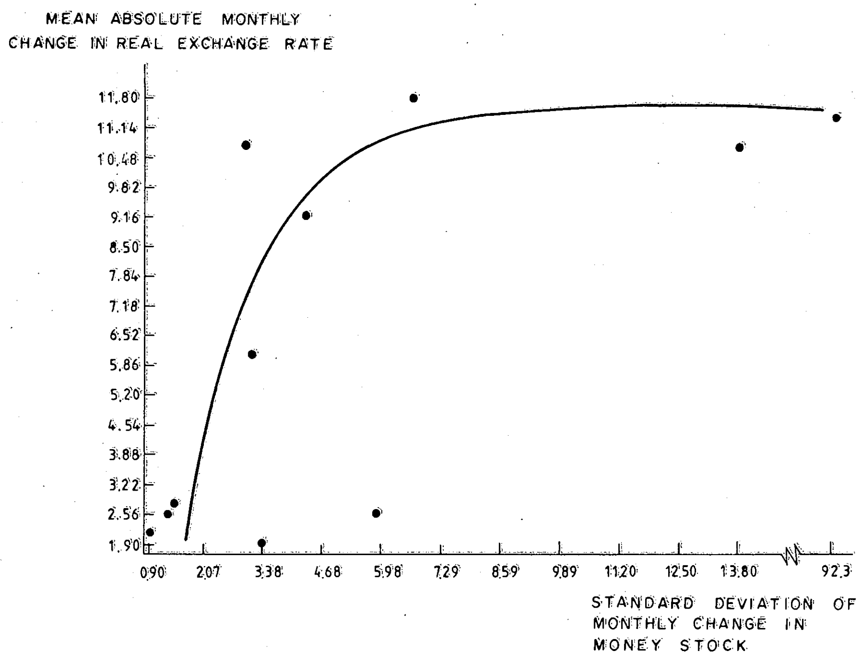
TABLE 9

MONETARY SHOCKS AND VARIABILITY IN REAL EXCHANGE RATES
(in percent)

	Mean Monthly Change in M2	*Standard Deviation of Monthly Change in M1 (1920s) and M2 (1970s)*	*Mean Monthly Change in Real Exchange Rate*
Germany (1922-23)	63.7	92.3	11.7
Chile (1973-74)	14.5	13.8	10.8
Argentina (1975-76)	7.3	6.6	11.8
Argentina (1980-82)	7.2	4.2	9.2
Israel (1977-81)	5.8	3.3	1.9
U.K. (1920-25)	5.6	5.8	2.7
Germany (1919-21)	4.8	2.9	10.7
Brazil (1973-82)	4.7	3.0	6.1
France (1973-82)	1.5	1.3	2.8
U.K. (1973-82)	1.4	1.2	2.6
Germany (1973-82)	1.1	0.9	2.3

These empirical results lead to the following interpretation. First, there is evidence that the monthly variability in real exchange rates increases with the variability in inflation and monetary growth rates. This phenomenon is observed over a wide range of countries and historical experiences. Second, the evidence confirms the hypothesis that variability in the real exchange rate levels off when inflation variability and monetary variability continue to increase. For example, at the height of the German hyperinflation, when monthly inflation rates far exceeded 100 percent, the average monthly deviations from PPP were not significantly higher than those that were observed in countries and in periods with inflation rates in the range of 10 to 20 percent per month. Our findings imply that the mean monthly deviations of the exchange rate from PPP do not greatly exceed 10 percent even if the rate of inflation increases to hyperinflationary proportions. This

FIGURE 7
MONETARY SHOCKS AND VARIABILITY IN THE
REAL EXCHANGE RATE



lends support to the idea that goods arbitrage becomes a very potent force when deviations from PPP increase, leading to quicker adjustments in the goods prices and thereby limiting the size of changes in the real exchange rate. Note, however, that our results contradict the view that deviations from PPP tended to disappear during the German hyperinflation. There is simply no such tendency.

One can also conclude from these results that the short-term variability in real exchange rates observed in major industrialized countries since 1973 was relatively low compared with the historical experience of other countries, and that this was due mainly to the substantially lower variability and level of inflation observed in the industrialized countries during that period.

A final comment on the empirical evidence relates to the experiences of France, Germany, and the United Kingdom since 1973. It appears from Table 7 that, despite lower inflation variability in Germany than in France or the United Kingdom, the variability of the German real exchange rate was not substantially lower than in France or the United Kingdom. This, of course, relates to the fact that all exchange rates are expressed in the common numeraire, the dollar. As a result, the variability of U.S. inflation also matters. Thus, given the U.S. experience with inflation during the 1970s, Germany could not compress the degree of real-exchange-rate variability very much by reducing its own inflation variability.

6 PURCHASING-POWER PARITY AND HYPERINFLATION

Jacob Frenkel's empirical work suggests that the PPP relationship is closer during periods of hyperinflation than during periods of low inflation. Our results suggest the opposite, that short-term deviations from PPP reach their highest levels during hyperinflationary periods. How can these conflicting results be interpreted?

Frenkel's empirical studies are based on regression of the exchange rate on the price level:

$$e_t = \alpha + \beta(p_t - p_{ft}) + u_t \,, \tag{16}$$

where p_t is the domestic price level and p_{ft} the foreign price level (both in logs). When this equation is estimated using German data for 1920 to 1923, the coefficient β is invariably close to 1, as shown in Table 10.

The theory developed in Chapter 4 allows us to clear up the apparent contradiction between our results and Frenkel's. Under hyperinflation, the stochastic disturbances affecting the *aa* curve are large compared with a regime with low inflation rates (see Figure 8). When regressing an equation like (16), the fit will tend to be better under hyperinflation than when inflation is low, despite the fact that short-term deviations from PPP are higher under hyperinflation. When the disturbances in the *aa* curve increase relative to the width of the transactions-cost band around PPP, the degree of covariation of p_t and e_t increases, leading to a coefficient β closer to 1. Thus, one can conclude that, although short-term deviations from PPP tend to be very high during hyperinflation, the price level tends to be a good predictor of the nominal exchange rate.

This analysis also explains an empirical phenomenon noted in Chapter 2. There we found that during the low-inflation period of the 1970s, the contemporaneous correlation between changes in nominal and real exchange rates tended to be high, whereas the contemporaneous correlation between changes in prices and the nominal exchange rate tended to be low. The opposite was observed during high- or hyperinflationary periods of the 1920s. This can easily be explained by Figure 8. During periods of low inflation, short-term price stickiness produces large covariation of real and nominal exchange rates. During hyperinflationary periods, however, e_t and p_t will be strongly correlated, with a corresponding decline in the correlation of e_t and θ_t.

TABLE 10

FRENKEL'S ESTIMATIONS OF EQUATION (16) FOR THE GERMAN HYPERINFLATION

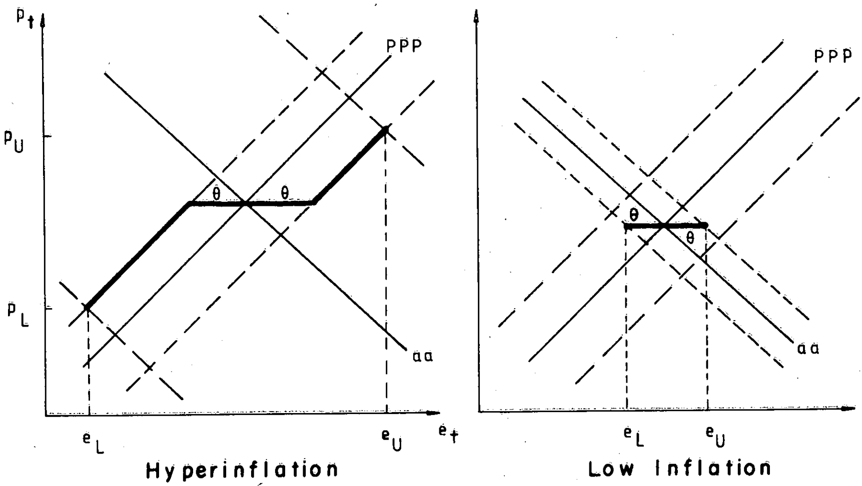
Independent Variable (p_t)	β
Wholesale price	1.006 (0.010)
Consumer price	1.076 (0.030)
Wages	1.076 (0.038)

SOURCE: Frenkel (1978).

NOTE: When estimating equation (16), p_{ft} is dropped because its variability is extremely small compared with the variability of p_t.

FIGURE 8

HYPERINFLATION AND LOW INFLATION



7 CONCLUSION

This Study systematically compared the variability of real exchange rates during the 1970s and the first half of the 1920s. The main findings can be summarized as follows. First, the exchange markets of major currencies were considerably more turbulent during the first half of the 1920s than during the recent period from 1973 to 1982. As a result, real exchange rates tended to exhibit stronger short-run variations during the 1920-26 period. Second, during the 1970s we observe high correlations between changes in real and nominal exchange rates but relatively low correlations between changes in prices and nominal exchange rates. The opposite pattern was observed during the 1920s. This suggests that price levels tended to be more flexible during the 1920s. The 1970s were characterized by short-term price rigidity.

In Chapter 4 we developed a theoretical framework aimed at explaining these empirical observations. Our model is very much influenced by Aizenman (1984). The main feature is that the degree of price stickiness is made endogenous. Deviations from PPP are then influenced by the sizes of the stochastic disturbances in the money market. This allowed us to show that the large differences across countries and periods in the real exchange rate can be explained quite well by the differences in monetary and inflation variability. Thus, the larger the size of the monetary and inflationary disturbances, the larger the variability of the real exchange rate. When a country moved toward hyperinflation, short-term variability in the real exchange rate hit the highest levels.

This relationship, however, is not linear. With increasing monetary (and inflationary) disturbances, the variability in the real exchange rate first increases and then tends to level off. The short-term variability during the German hyperinflation was about the same as during the 1970s in Latin American countries with high monetary disturbances. This indicates that the forces of goods arbitrage become strong enough to prevent variability from increasing in proportion to the sizes of the monetary disturbances.

This theoretical framework also allowed us to explain why we observe a relatively high correlation between changes in nominal and real exchange rates during the 1970s, and a relatively high correlation between changes in prices and nominal exchange rates during the 1920s. Here again, the driving force is the size of the unexpected monetary disturbances. When these are low, short-term price rigidity is the rule, so that changes in nominal and real exchange rates are highly correlated. When the size of the monetary disturbances increases, the degree of short-term price flexibility increases. This tends to increase the correlation between short-term changes in prices and nominal exchange rates.

In this Study we have stressed that the large differences in the degree of exchange-rate variability across countries can be explained, at least partially, by differences in monetary and inflationary experiences. The evidence provided here should not be interpreted to mean that only monetary factors matter: there is certainly enough unexplained variability in real exchange rates to allow a role for nonmonetary factors.

APPENDIX A

Alternative Measures of Real Exchange Rates

TABLE A-1

Mean and Standard Deviation of Monthly Absolute Changes in Real Exchange Rates, Material-Price or Cost-of-Living Index and Consumer-Price Index, 1920 and 1970s

(in percent)

	Mean Absolute Change	*Standard Deviation*	*Range*
1920s:			
franc/dollar (1921-26) (material-price index)	3.6	3.5	27.8
mark/dollar (1920-23) (cost-of-living index)	19.8	16.8	78.3
sterling/dollar (1921-25) (material-price index)	2.0	1.7	13.5
1970s (CPI):			
franc/dollar (1973-82)	2.1	1.9	15.4
mark/dollar (1973-82)	2.3	2.0	16.7
sterling/dollar (1973-82)	2.1	1.5	16.0

NOTE: The material-price index is an index comparable to the cost-of-living index.

TABLE A-2

Mean and Standard Deviation of Monthly Absolute Changes in the Material-Price Index and the Consumer-Price Index, 1920s and 1970s

(in percent)

	Mean Absolute Change	*Standard Deviation*	*Range*
1920s:			
France (material price)	3.9	3.5	27.8
Germany (cost of living)	56.5	121.7	548.8
U.K. (material price)	2.2	1.6	12.4
U.S. (material price)	1.8	1.9	19.8
1970s (CPI):			
France	0.8	0.3	12.0
Germany	0.4	0.3	1.5
U.K.	1.1	0.8	4.2
U.S.	0.7	0.3	1.9

NOTE: See Note to Table A-1.

APPENDIX B
Data Description

1920s

All prices for France, the U.K., and the U.S. are from Tinbergen (1934). The wholesale- and the material-price indices for France are from pp. 72-73, cols. 34 and 36; those for the U.K. are from pp. 105-106, cols. 21 and 25; those for the U.S. are from pp. 210-211, cols. 28-29.

Share prices for France and the U.K. are also from Tinbergen (1934). For France, the stock-price index is from pp. 66-67, col. 3. For the U.K., the price index is for 20 industrials from pp. 102-103, col. 2.

For Germany, all prices are from Bresciani-Turroni (1939). Index numbers of wholesale prices are from pp. 442-443. Cost-of-living (consumer price) index numbers are from p. 444. For the share prices, the index of German stock prices was adjusted according to index numbers of wholesale prices, pp. 452-454.

The franc/sterling and sterling/dollar exchange rate are from Einzig (1937), Appendix I. The franc/dollar exchange rate was calculated using triangular arbitrage.

An index for the German exchange rate was computed by using the so-called "paper prices" (an index close to the CPI) and gold prices.

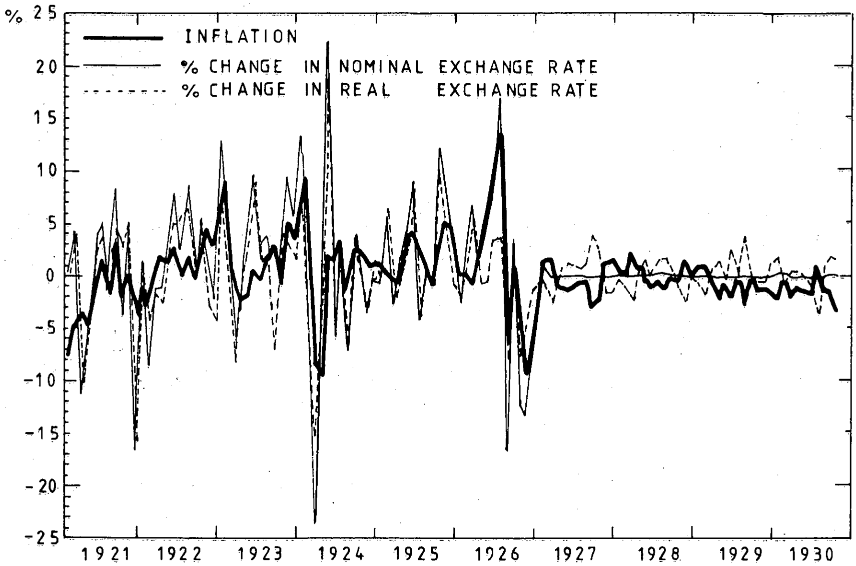
1970s

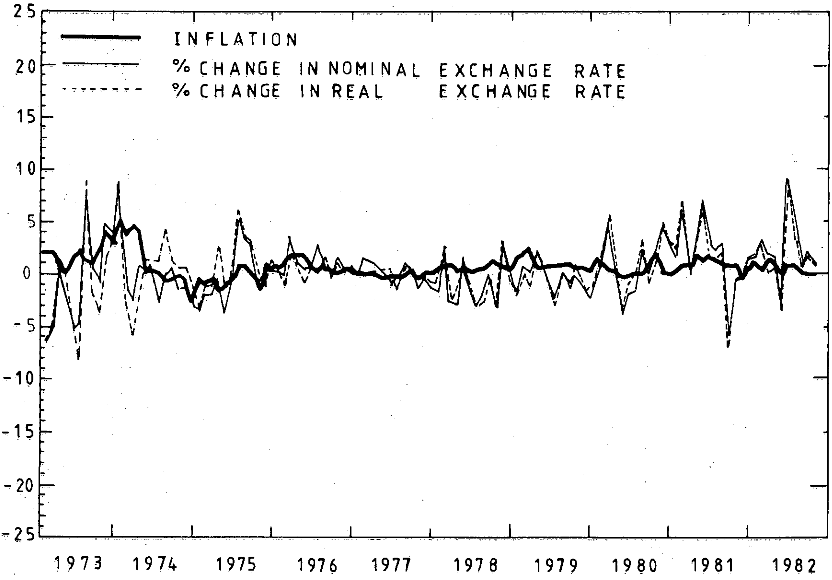
All data on exchange rates and prices (wholesale-price index and consumer-price index) are from International Financial Statistics (IMF), lines rf. 63 and 64.

Data on share prices for France, Germany, and the U.K. are from Main Economic Indicators (OECD), various issues.

APPENDIX C
Exchange Rates and Inflation

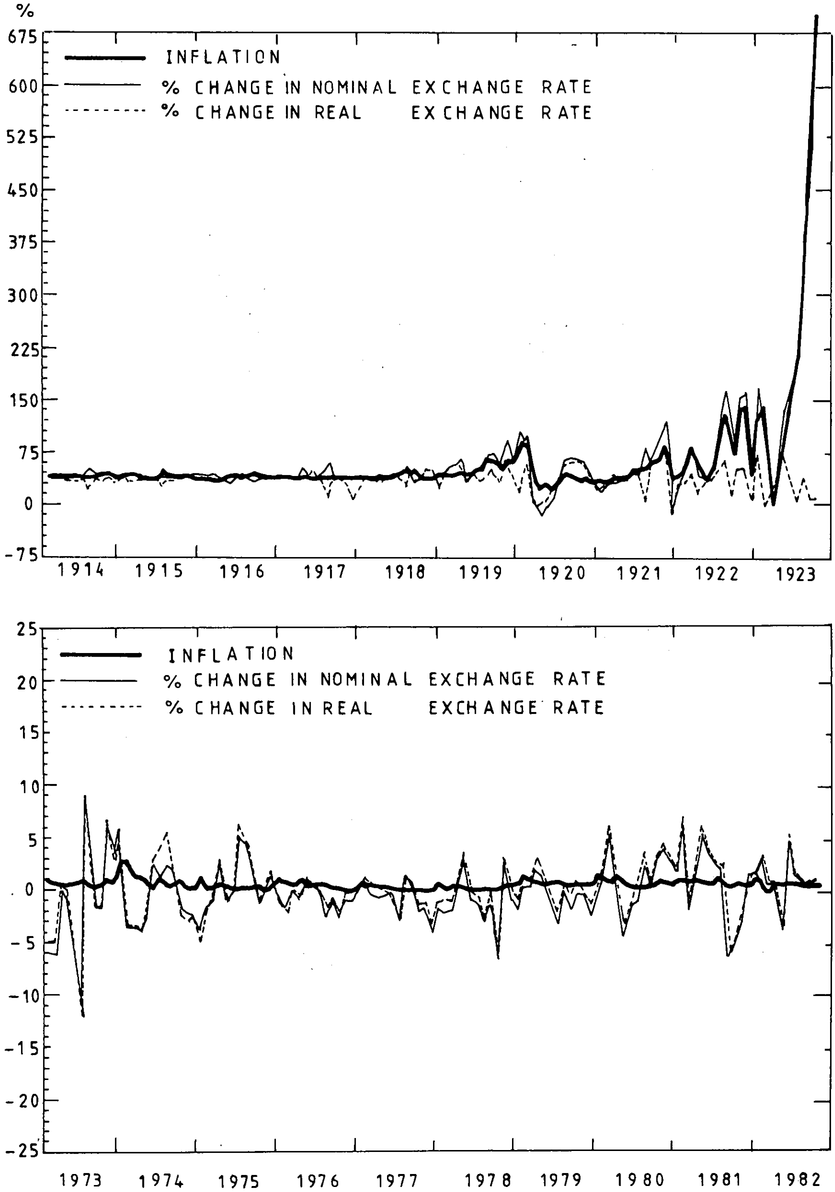
FIGURE C-1
Exchange Rates and Inflation, France,
1921-30, 1973-82





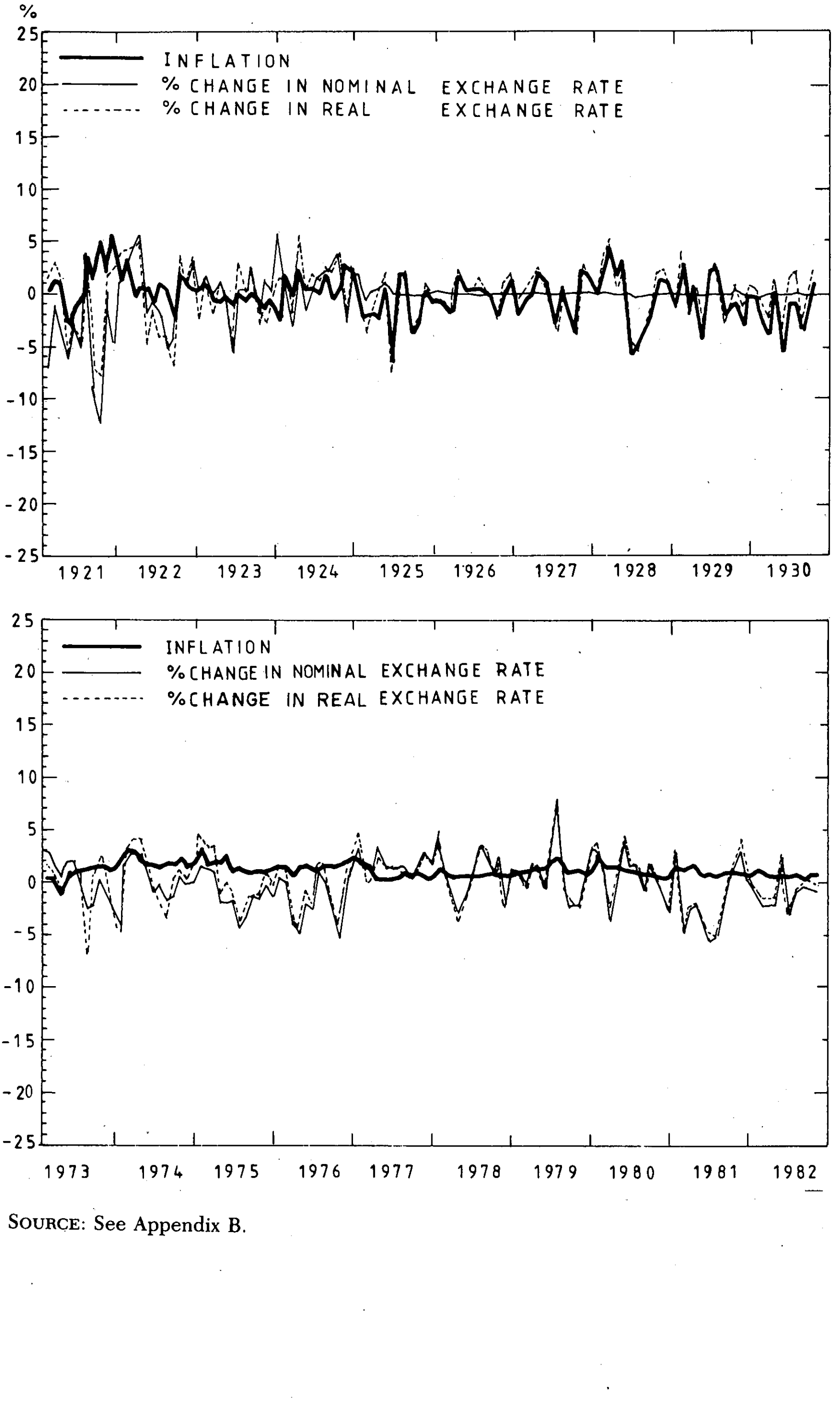
Source: See Appendix B.

FIGURE C-2
EXCHANGE RATES AND INFLATION, GERMANY,
1914-23, 1973-82



SOURCE: See Appendix B.

FIGURE C-3
EXCHANGE RATES AND INFLATION, UNITED KINGDOM, 1921-30, 1973-82



SOURCE: See Appendix B.

APPENDIX D

SPECTRAL ANALYSIS OF REAL EXCHANGE RATES

As a first step in the spectral analysis of real exchange rates, we checked for stationarity in the mean, the variance, and the covariance.

Standard regression analysis is used to test for mean stationarity. We first regressed the real exchange rate on a constant; we then added linear and quadratic trend variables. An F-test was then performed to determine whether the trend variables improve the fit. The results are given in Table D-1. The period 1973-82 was split in two to make it more comparable to the period 1919-23. This yields sample periods for the 1920s and the 1970s of roughly the same length (Table D-2).

We can conclude from Tables D-1 and D-2 that during the full period of the 1970s the hypothesis that real exchange rates showed trendlike behavior cannot be rejected. It can be rejected for the mark/dollar rates during 1919-23. Note also that when the 1970s are split into two subperiods, no trend appears in the real pound/dollar rate. This suggests a break in the data around 1978, so that for the whole sample period a trend does show up.

To test for stationarity in the variance, we computed the standard deviations of the yearly exchange rates over one-year periods. The results are shown in Table D-3. We can conclude that there is little trendlike behavior in the variability of the real exchange rate and that the series are stationary in the variance.

Finally, the data were checked for stationarity in the covariance. To do so, the sample periods were divided into two subperiods of equal length, and the periodogram was calculated for each of the subperiods. If the shape of the periodogram is equal in the subperiods, the series is stationary in the autocovariances. The results are shown in Tables D-4 and D-5.

During the 1920s we find evidence of nonstationarity for the U.K. It can be seen that the periodogram peaks at a cycle of 1 year 3 months during the first half of the period, whereas it peaks at a much larger cycle (2 years 6 months) during the second half. No evidence of nonstationarity in the covariance is found for France and Germany during the 1920s.

During the 1970s we find some evidence of nonstationarity in the covariance for France and Germany. For example, in the case of France during the sample period 1978-82 the ranking of the cycles is reversed, suggesting a shift in the autocovariance structure of the real exchange rate during 1978-82.

TABLE D-1

F-TESTS FOR SIGNIFICANCE OF LINEAR AND QUADRATIC TRENDS IN THE REAL EXCHANGE RATE, EARLY 1920s AND 1973-82

	F-Ratio
1920s:	
franc/dollar (1921-26)	37.83**
mark/dollar (1919-23)	2.98
sterling/dollar (1921-25)	4.56*
1970s:	
franc/dollar (1973-82)	116.30**
mark/dollar (1973-82)	14.90**
sterling/dollar (1973-82)	143.80**

* Exceeds critical F-ratio at 95% confidence level.
** Exceeds critical F-ratio at 99% confidence level.

TABLE D-2

F-TESTS FOR SIGNIFICANCE OF LINEAR AND QUADRATIC TRENDS IN THE REAL EXCHANGE RATE, 1973-78 AND 1978-82

	F-Ratio
1973-78:	
franc/dollar	92.90**
mark/dollar	0.005
sterling/dollar	2.78
1978-82:	
franc/dollar	109.00**
mark/dollar	161.60**
sterling/dollar	0.12

** Exceeds critical F-ratio at 99% confidence level.

TABLE D-3

STANDARD DEVIATIONS OF MONTHLY REAL EXCHANGE RATES

	franc/dollar	*mark/dollar*	*sterling/dollar*
1920s:			
1919		18.1	
1920		23.8	
1921	5.4	21.3	8.1
1922	7.7	12.4	6.0
1923	4.6	23.7	3.1
1924	7.6		5.8
1925	6.2		4.5
1926	7.2		
1970s:			
1973	6.6	6.9	2.4
1974	3.2	4.0	3.8
1975	3.4	5.7	4.7
1976	0.7	2.3	4.2
1977	1.0	1.9	5.2
1978	6.8	4.2	3.7
1979	3.8	2.9	6.6
1980	2.5	2.7	4.5
1981	5.3	5.8	11.2
1982	5.6	1.7	2.7

TABLE D-4

COMPARISON OF PEAK FREQUENCIES IN TWO SUBPERIODS OF EQUAL LENGTH, 1920s

	Frequency	*Length of Cycle*	*Periodogram Value*
France:			
Subperiod 1	0.028	3 yrs	628
	0.083	1 yr	452
Subperiod 2	0.028	3 yrs	2133
Germany:			
Subperiod 1	0.067	1 yr 3 mos	5927
	0.100	10 mos	1227
Subperiod 2	0.033	2 yrs 6 mos	1510
	0.067	1 yr 3 mos	3891
	0.100	10 mos	3330
U.K.:			
Subperiod 1	0.033	2 yrs 6 mos	224
	0.066	1 yr 3 mos	714
	0.100	10 mos	267
Subperiod 2	0.033	2 yrs 6 mos	723

TABLE D-5

COMPARISON OF PEAK FREQUENCIES IN TWO SUBPERIODS OF EQUAL LENGTH, 1970S

	Frequency	*Length of Cycle*	*Periodogram Value*
France:			
1973-77:			
Subperiod 1	0.033	2 yrs 6 mos	148
	0.067	1 yr 3 mos	114
	0.100	10 mos	315
Subperiod 2	0	No trend: flat	25
		spectrum no peaks	75
1978-82:			
Subperiod 1	0.033	2 yrs 6 mos	1792
	0.067	1 yr 3 mos	575
Subperiod 2	0.036	2 yrs 4 mos	441
	0.071	1 yr 2 mos	988
Germany:			
1973-77:			
Subperiod 1	0.067	1 yr 3 mos	136
	0.100	10 mos	471
Subperiod 2	0.067	1 yr 3 mos	205
1978-82:			
Subperiod 1	0.033	2 yrs 6 mos	738
	0.062	1 yr 3 mos	258
Subperiod 2	0.036	2 yrs 4 mos	312
	0.071	1 yr 2 mos	379
	0.143	7 mos	138
U.K.:			
1973-77			
Subperiod 1	0.330	2 yrs 6 mos	459
	0.100	10 mos	238
Subperiod 2	0.033	2 yrs 6 mos	867
1978-82			
Subperiod 1	0.033	2 yrs 6 mos	1983
Subperiod 2	0.036	2 yrs 4 mos	3218
	0.071	1 yr 2 mos	1081

FIGURE D-1
SPECTRUM OF REAL EXCHANGE RATE, FRANCE,
1921-26, 1973-77, 1978-82

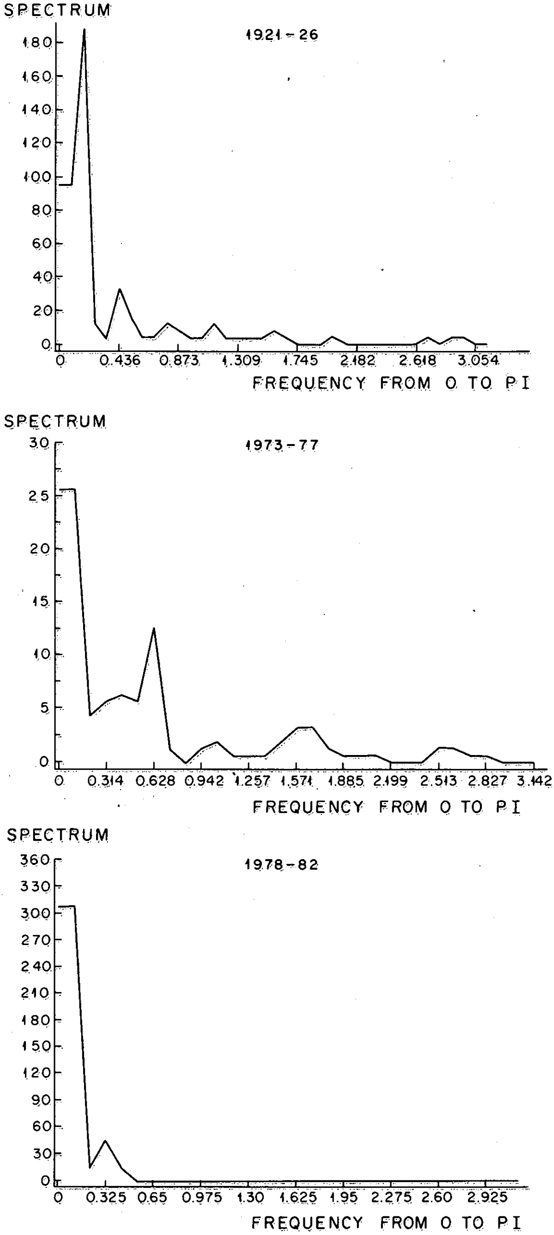


FIGURE D-2

SPECTRUM OF REAL EXCHANGE RATE, GERMANY, 1919-23, 1973-77, 1978-82

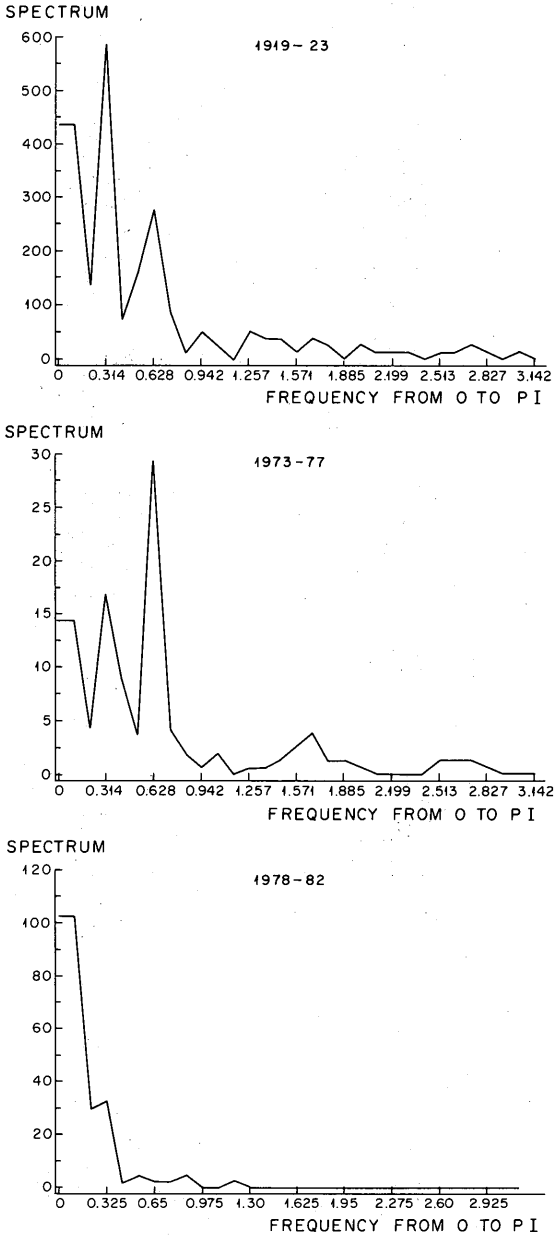
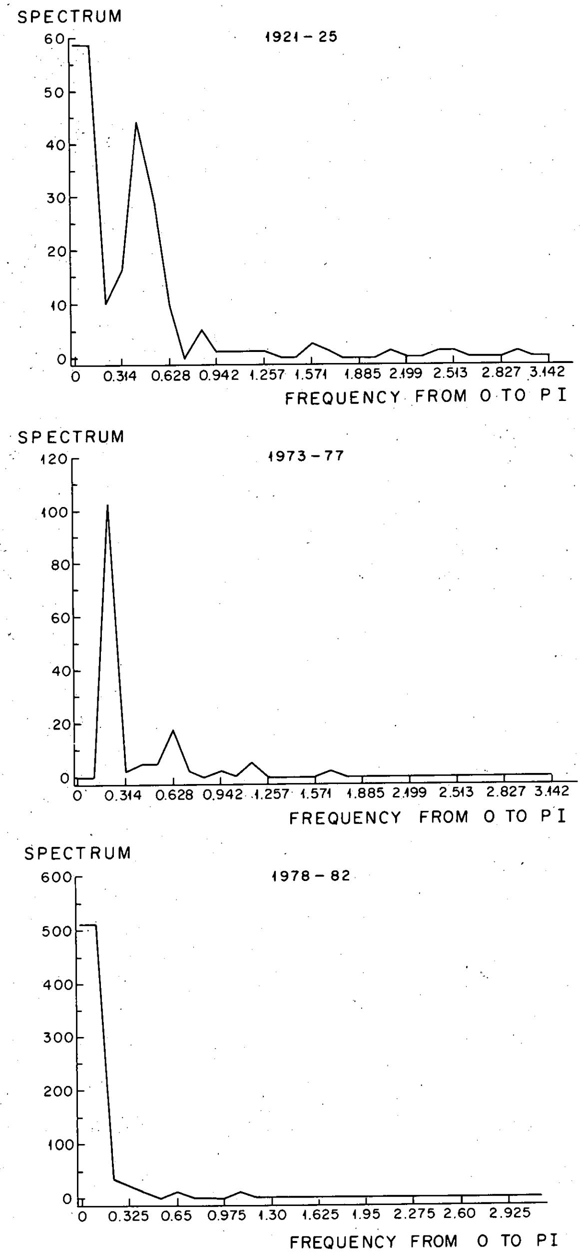


FIGURE D-3

SPECTRUM OF REAL EXCHANGE RATE, UNITED KINGDOM, 1921-25, 1973-77, 1978-82



REFERENCES

Aizenman, Joshua, "Modeling Deviations from Purchasing Power Parity," *International Economic Review*, 25 (February 1984), pp. 175-191.

Aliber, Robert Z., "Floating Exchange Rates: The Twenties and the Seventies," in John Chipman and Charles Kindleberger, *Flexible Exchange Rates and the Balance of Payments*, Amsterdam, North-Holland, 1980.

Bresciani-Turroni, C., *The Economics of Inflation*, London, 1937.

de Jonge, A., *The Weimar Chronicle: Prelude to Hitler*, New York, Meridian, 1979.

Dornbusch, Rudiger, "Expectations and Exchange Rate Dynamics," *Journal of Political Economy*, 84 (December 1976), pp. 1161-1176.

Emminger, Otmar, "Economic Instability and Flexible Exchange Rates," in Henry C. Wallich et al., *World Money and National Policies*, Occasional Papers No. 12, New York, Group of Thirty, 1983.

Frankel, Jeffrey A., "Tests of Monetary and Portfolio Balance Models," in John Bilson and Richard Marston, eds., *Exchange Rate Theory and Practice*, Chicago, University of Chicago Press, 1984.

Frenkel, Jacob A., "Purchasing Power Parity: Doctrinal Perspective and Evidence from the 1920's," *Journal of International Economics*, 8 (May 1978), pp. 169-193.

———, "The Collapse of Purchasing Power Parities during the 1970s," *European Economic Review*, 7 (May 1981), pp. 145-165.

———, "Flexible Exchange Rates, Prices and the Role of News: Lessons from the 1970s," *Journal of Political Economy*, 89 (August 1981), pp. 665-705.

Katseli, Louka T., *The Reemergence of the Purchasing Power Parity Doctrine in the 1970s*, Special Paper in International Economics No. 13, Princeton, N.J., Princeton University, International Finance Section, December 1979.

Kenen, Peter B., "Exchange Rate Instability: Measurement and Implications," Research Memorandum, Princeton, N.J., Princeton University, International Finance Section, June 1979.

Kenen, Peter B., and D. Rodrik, "Measuring and Analyzing the Effects of Short-Term Volatility in Real Exchange Rates," Working Papers in International Economics No. G-84-01, Princeton, N.J., Princeton University, International Finance Section, March 1984.

Kravis, Irving B., and Robert E. Lipsey, *Toward an Explanation of National Price Levels*, Studies in International Finance No. 52, Princeton, N.J., Princeton University, International Finance Section, November 1983.

Lanyi, Anthony, and Esther Suss, "Exchange Rate Variability: Alternative Measures and Interpretation," *IMF Staff Papers*, 29 (December 1982), pp. 527-560.

Levich, Richard M., *Overshooting in the Foreign Exchange Market*, Occasional Papers No. 5, New York, Group of Thirty, 1981.

———, "Empirical Studies of Exchange Rates: Price Behavior, Rate Determination and Market Efficiency," in Ronald W. Jones and Peter B. Kenen, eds., *Handbook of International Economics*, Amsterdam, North-Holland, 1985.

Mussa, Michael, "The Exchange Rate, the Balance of Payments and Monetary and

Fiscal Policy under a Regime of Controlled Floating," *Scandinavian Journal of Economics*, 78 (May 1976), pp. 229-248.
Officer, Lawrence, *Purchasing Power Parity and Exchange Rates: Theory, Evidence and Relevance*, New York, JAI Press, 1982.
Tinbergen, Jan, ed., *International Abstract of Economic Statistics 1919-1930*, London, International Conference of Economic Services, 1934.
Williamson, John, *The Exchange Rate System*, Policy Analyses in International Economics No. 4, Washington, D.C., Institute for International Economics, September 1983.

PUBLICATIONS OF THE INTERNATIONAL FINANCE SECTION

Notice to Contributors

The International Finance Section publishes at irregular intervals papers in four series: ESSAYS IN INTERNATIONAL FINANCE, PRINCETON STUDIES IN INTERNATIONAL FINANCE, SPECIAL PAPERS IN INTERNATIONAL ECONOMICS, and REPRINTS IN INTERNATIONAL FINANCE. ESSAYS and STUDIES are confined to subjects in international finance. SPECIAL PAPERS are surveys of the literature suitable for courses in colleges and universities.

An ESSAY should be a lucid exposition of a theme, accessible not only to the professional economist but to other interested readers. It should therefore avoid technical terms, should eschew mathematics and statistical tables (except when essential for an understanding of the text), and should rarely have footnotes.

A STUDY or SPECIAL PAPER may be more technical. It may include statistics and algebra and may have many footnotes. STUDIES and SPECIAL PAPERS may also be longer than ESSAYS; indeed, these two series are meant to accommodate manuscripts too long for journal articles and too short for books.

To facilitate prompt evaluation, please submit three copies of your manuscript. Retain one for your files. The manuscript should be typed on one side of 8½ by 11 strong white paper. All material should be double-spaced—text, excerpts, footnotes, tables, references, and figure legends. For more complete guidance, prospective contributors should send for the Section's style guide before preparing their manuscripts.

How to Obtain Publications

A mailing list is maintained for free distribution of all new publications to college, university, and public libraries and nongovernmental, nonprofit research institutions.

Individuals and organizations not qualifying for free distribution can obtain ESSAYS and REPRINTS as issued and announcements of new STUDIES and SPECIAL PAPERS by paying a fee of $10 (within U.S.) or $12 (outside U.S.) to cover the period January 1 through December 31, 1985. Alternatively, for $30 they can receive all publications automatically—SPECIAL PAPERS and STUDIES as well as ESSAYS and REPRINTS.

ESSAYS and REPRINTS can also be ordered from the Section at $2.50 per copy, and STUDIES and SPECIAL PAPERS at $4.50. Payment MUST be included with the order and MUST be made in U.S. dollars. PLEASE INCLUDE $1 FOR POSTAGE AND HANDLING. (These charges are waived on orders from persons or organizations in countries whose foreign-exchange regulations prohibit such remittances.) For airmail delivery outside U.S., Canada, and Mexico, there is an additional charge of $1.

All manuscripts, correspondence, and orders should be addressed to:

International Finance Section
Department of Economics, Dickinson Hall
Princeton University
Princeton, New Jersey 08544

Subscribers should notify the Section promptly of a change of address, giving the old address as well as the new one.

List of Recent Publications

Some earlier issues are still in print. Write the Section for information.

ESSAYS IN INTERNATIONAL FINANCE

130. Franco Modigliani and Tommaso Padoa-Schioppa, *The Management of an Open Economy with "100% Plus" Wage Indexation*. (Dec. 1978)
131. H. Robert Heller and Malcolm Knight, *Reserve-Currency Preferences of Central Banks*. (Dec. 1978)
132. Robert Triffin, *Gold and the Dollar Crisis: Yesterday and Tomorrow*. (Dec. 1978)
133. Herbert G. Grubel, *A Proposal for the Establishment of an International Deposit Insurance Corporation*. (July 1979)
134. Bertil Ohlin, *Some Insufficiencies in the Theories of International Economic Relations*. (Sept. 1979)
135. Frank A. Southard, Jr., *The Evolution of the International Monetary Fund*. (Dec. 1979)
136. Niels Thygesen, *Exchange-Rate Experiences and Policies of Small Countries: Some European Examples in the 1970s*. (Dec. 1979)
137. Robert M. Dunn, Jr., *Exchange Rates, Payments Adjustments, and OPEC: Why Oil Deficits Persist*. (Dec. 1979)
138. Tom de Vries, *On the Meaning and Future of the European Monetary System*. (Sept. 1980)
139. Deepak Lal, *A Liberal International Economic Order: The International Monetary System and Economic Development*. (Oct. 1980)
140. Pieter Korteweg, *Exchange-Rate Policy, Monetary Policy, and Real Exchange-Rate Variability*. (Dec. 1980)
141. Bela Balassa, *The Process of Industrial Development and Alternative Development Strategies*. (Dec. 1980)
142. Benjamin J. Cohen, *The European Monetary System: An Outsider's View*. (June 1981)
143. Marina v. N. Whitman, *International Trade and Investment: Two Perspectives*. (July 1981)
144. Sidney Dell, *On Being Grandmotherly: The Evolution of IMF Conditionality*. (Oct. 1981)
145. Ronald I. McKinnon and Donald J. Mathieson, *How to Manage a Repressed Economy*. (Dec. 1981)

*146. Bahram Nowzad, *The IMF and Its Critics*. (Dec. 1981)

147. Edmar Lisboa Bacha and Carlos F. Díaz Alejandro, *International Financial Intermediation: A Long and Tropical View*. (May 1982)
148. Alan A. Rabin and Leland B. Yeager, *Monetary Approaches to the Balance of Payments and Exchange Rates*. (Nov. 1982)
149. C. Fred Bergsten, Rudiger Dornbusch, Jacob A. Frenkel, Steven W. Kohlhagen, Luigi Spaventa, and Thomas D. Willett, *From Rambouillet to Versailles: A Symposium*. (Dec. 1982)

*Out of print. Available on demand in xerographic paperback or library-bound copies from University Microfilms International, Box 1467, Ann Arbor, Michigan 48106, United States, and 30-32 Mortimer St., London, WIN 7RA, England. Paperback reprints are usually $20. Microfilm of all Essays by year is also available from University Microfilms. Photocopied sheets of out-of-print titles are available on demand from the Section at $6 per Essay and $8 per Study or Special Paper.

150. Robert E. Baldwin, *The Inefficacy of Trade Policy*. (Dec. 1982)
151. Jack Guttentag and Richard Herring, *The Lender-of-Last Resort Function in an International Context*. (May 1983)
152. G. K. Helleiner, *The IMF and Africa in the 1980s*. (July 1983)
153. Rachel McCulloch, *Unexpected Real Consequences of Floating Exchange Rates*. (Aug. 1983)
154. Robert M. Dunn, Jr., *The Many Disappointments of Floating Exchange Rates*. (Dec. 1983)
155. Stephen Marris, *Managing the World Economy: Will We Ever Learn?* (Oct. 1984)
156. Sebastian Edwards, *The Order of Liberalization of the External Sector in Developing Countries*. (Dec. 1984)
157. Wilfred J. Ethier and Richard C. Marston, eds., with Kindleberger *et al.*, *International Financial Markets and Capital Movements: A Symposium in Honor of Arthur I. Bloomfield*. (Sept. 1985)

PRINCETON STUDIES IN INTERNATIONAL FINANCE

44. Clas Wihlborg, *Currency Risks in International Financial Markets*. (Dec. 1978)
45. Ian M. Drummond, *London, Washington, and the Management of the Franc, 1936-39*. (Nov. 1979)
46. Susan Howson, *Sterling's Managed Float: The Operations of the Exchange Equalisation Account, 1932-39*. (Nov. 1980)
47. Jonathan Eaton and Mark Gersovitz, *Poor-Country Borrowing in Private Financial Markets and the Repudiation Issue*. (June 1981)
48. Barry J. Eichengreen, *Sterling and the Tariff, 1929-32*. (Sept. 1981)
49. Peter Bernholz, *Flexible Exchange Rates in Historical Perspective*. (July 1982)
50. Victor Argy, *Exchange-Rate Management in Theory and Practice*. (Oct. 1982)
51. Paul Wonnacott, *U.S. Intervention in the Exchange Market for DM, 1977-80*. (Dec. 1982)
52. Irving B. Kravis and Robert E. Lipsey, *Toward an Explanation of National Price Levels*. (Nov. 1983)
53. Avraham Ben-Bassat, *Reserve-Currency Diversification and the Substitution Account*. (March 1984)
54. Jeffrey Sachs, *Theoretical Issues in International Borrowing*. (July 1984)
55. Marsha R. Shelburn, *Rules for Regulating Intervention under a Managed Float*. (Dec. 1984)
56. Paul De Grauwe, Marc Janssens, and Hilde Leliaert, *Real-Exchange-Rate Variability from 1920 to 1926 and 1973 to 1982*. (Sept. 1985)

SPECIAL PAPERS IN INTERNATIONAL ECONOMICS

8. Jagdish Bhagwati, *The Theory and Practice of Commercial Policy: Departures from Unified Exchange Rates*. (Jan. 1968)

*9. Marina von Neumann Whitman, *Policies for Internal and External Balance*. (Dec. 1970)

10. Richard E. Caves, *International Trade, International Investment, and Imperfect Markets*. (Nov. 1974)

*11. Edward Tower and Thomas D. Willett, *The Theory of Optimum Currency Areas and Exchange-Rate Flexibility*. (May 1976)

*12. Ronald W. Jones, *"Two-ness" in Trade Theory: Costs and Benefits*. (April 1977)

13. Louka T. Katseli-Papaefstratiou, *The Reemergence of the Purchasing Power Parity Doctrine in the 1970s*. (Dec. 1979)

*14. Morris Goldstein, *Have Flexible Exchange Rates Handicapped Macroeconomic Policy?* (June 1980)

15. Gene M. Grossman and J. David Richardson, *Strategic Trade Policy: A Survey of Issues and Early Analysis*. (April 1985)

REPRINTS IN INTERNATIONAL FINANCE

18. Peter B. Kenen, *Floats, Glides and Indicators: A Comparison of Methods for Changing Exchange Rates*. [Reprinted from *Journal of International Economics*, 5 (May 1975).] (June 1975)

19. Polly R. Allen and Peter B. Kenen, *The Balance of Payments, Exchange Rates, and Economic Policy: A Survey and Synthesis of Recent Developments*. [Reprinted from Center of Planning and Economic Research, Occasional Paper 33, Athens, Greece, 1978.] (April 1979)

20. William H. Branson, *Asset Markets and Relative Prices in Exchange Rate Determination*. [Reprinted from *Sozialwissenschaftliche Annalen*, Vol. 1, 1977.] (June 1980)

21. Peter B. Kenen, *The Analytics of a Substitution Account*. [Reprinted from *Banca Nazionale del Lavoro Quarterly Review*, No. 139 (Dec. 1981).] (Dec. 1981)

22. Jorge Braga de Macedo, *Exchange Rate Behavior with Currency Inconvertibility*. [Reprinted from *Journal of International Economics*, 12 (Feb. 1982).] (Sept. 1982)

23. Peter B. Kenen, *Use of the SDR to Supplement or Substitute for Other Means of Finance*. [Reprinted from George M. von Furstenberg, ed., *International Money and Credit: The Policy Roles*, Washington, IMF, 1983, Chap. 7.] (Dec. 1983)

ISBN 0-88165-228-8