Integration of Short-Run Exchange Rate Dynamics With Long-Run Equilibrium: An Empirical Analysis

Sugata Biswas
Utah State University

Follow this and additional works at: https://digitalcommons.usu.edu/etd

Part of the Economics Commons

Recommended Citation
Biswas, Sugata, "Integration of Short-Run Exchange Rate Dynamics With Long-Run Equilibrium: An Empirical Analysis" (1993). All Graduate Theses and Dissertations. 3847.
https://digitalcommons.usu.edu/etd/3847
INTEGRATION OF SHORT-RUN EXCHANGE RATE
DYNAMICS WITH LONG-RUN EQUILIBRIUM:
AN EMPIRICAL ANALYSIS

by

Sugata Biswas

A thesis submitted in partial fulfillment
of the requirements for the degree
of
MASTER OF ARTS
in
Economics

Approved:

Terrence F. Glover
Major Professor

Donald L. Snyder
Committee Member

L. Dwight Israelsen
Committee Member

James P. Shaver
Dean of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

1993
ACKNOWLEDGMENTS

First of all, I would like to thank Dr. Terry Glover, whose enormous investment of time and energy into this thesis was beyond reasonable expectations. A summary of his contributions, both direct and indirect, would easily fill a number of pages. Without his guidance, this thesis would not have been possible. I would also like to thank Dr. Donald Snyder and Dr. Dwight Israelsen for their helpful comments and encouragements during the many stages of this thesis.

I would like to especially thank Sandy Lee, Sarita Mohapatra, and Suzette Alder for their help during the critical phase of this thesis.

I would like to give special thanks to my parents and my wife. Their love and support have been immeasurable. They have been a source of inspiration and strength for me.

Sugata Biswas
CONTENTS

ACKNOWLEDGMENTS .......................................................... ii
LIST OF TABLES ................................................................... v
LIST OF FIGURES .............................................................. vi
ABSTRACT ........................................................................... vii

CHAPTER

I. INTRODUCTION ............................................................... 1
   Background .................................................................... 1
   Statement of Problem ..................................................... 3
   Objectives ..................................................................... 4

II. REVIEW OF THE HISTORICAL DEVELOPMENT OF
    EXCHANGE RATE REGIMES ............................................. 6
   The Gold Standard: 1870-1914 ..................................... 6
   The Interwar Years: 1918-1939 ................................. 9
   The Bretton Woods System: 1945-1973 ............... 12

III. EXCHANGE RATE BEHAVIOR AND MACROECONOMIC
    VARIABLES ................................................................. 17
    Exchange Rates and Their
    Determination ............................................................ 17
    Interest Rate Determination .................................... 20
    Money, Interest Rate and the
    Exchange Rate ........................................................... 23
    Permanent Changes in the Money
    Supply and the Exchange Rate .............................. 25
    Exchange Rate Overshooting ................................... 27
    Long Run Exchange Rates and
    Purchasing Power Parity ........................................... 28

IV. A REVIEW OF THE DORNBUSCH AND DRISKILL
    MODELS ........................................................................ 30
    The Dornbusch Model ............................................... 31
    Driskill's Estimation .................................................. 37
    The Stock/Flow Model ................................................ 39
<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Johansen Maximum Likelihood Procedure Cointegration LR Test Based on Maximal Eigenvalue of the Stochastic Matrix</td>
<td>57</td>
</tr>
<tr>
<td>2</td>
<td>Johansen Maximum Likelihood Procedure Cointegration LR Test Based on Trace of the Stochastic Matrix</td>
<td>57</td>
</tr>
<tr>
<td>3</td>
<td>Estimated Cointegrated Vectors, $\beta$, with Maximum Lag of the VAR Equal to 2</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>Estimated Adjustment Matrix, $\alpha$, with Maximum Lag of the VAR Equal to 2</td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td>Estimated Long-Run Matrix, $\Pi = \alpha P'$</td>
<td>63</td>
</tr>
<tr>
<td>6</td>
<td>Likelihood Ratio Test Statistics for Trivial Cointegrating Vectors</td>
<td>66</td>
</tr>
<tr>
<td>7</td>
<td>Likelihood Ratio Statistics for Tests of Cointegration Between Monetary Model Fundamentals</td>
<td>67</td>
</tr>
<tr>
<td>8</td>
<td>Likelihood Ratio Statistics for the Tests of the Absence of a Variable from All Cointegrating Vectors</td>
<td>69</td>
</tr>
<tr>
<td>9</td>
<td>Likelihood Ratio Statistics for Testing for the Same Restrictions in All Nontrivial Cointegrating Vectors</td>
<td>71</td>
</tr>
<tr>
<td>10</td>
<td>Likelihood Ratio Test Statistics for Tests of Weak Exogeneity of Each Variable</td>
<td>75</td>
</tr>
</tbody>
</table>
### LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Determination of the equilibrium dollar/DM exchange rate</td>
<td>19</td>
</tr>
<tr>
<td>2</td>
<td>Effect of a rise in the dollar interest rate</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>Determination of the equilibrium interest rate by the equality of aggregate real money demand and the real money supply</td>
<td>21</td>
</tr>
<tr>
<td>4</td>
<td>Effect of a rise in the money supply on the interest rate for a given price level and real income level</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>Simultaneous equilibrium in the U.S. money market and the foreign-exchange market</td>
<td>23</td>
</tr>
<tr>
<td>6</td>
<td>Effect on the dollar/DM exchange rate and dollar interest rate of an increase in the U.S. money supply</td>
<td>24</td>
</tr>
<tr>
<td>7</td>
<td>Short-run and long-run effects of an increase in the U.S. money supply</td>
<td>25</td>
</tr>
<tr>
<td>8</td>
<td>Time paths of U.S. economic variables after a permanent increase in the U.S. money supply</td>
<td>27</td>
</tr>
<tr>
<td>9</td>
<td>Residuals of cointegrating vector 1</td>
<td>61</td>
</tr>
<tr>
<td>10</td>
<td>Residuals of cointegrating vector 2</td>
<td>62</td>
</tr>
<tr>
<td>11</td>
<td>Residuals of cointegrating vector 3</td>
<td>62</td>
</tr>
</tbody>
</table>
ABSTRACT

Integration of Short-Run Exchange Rate Dynamics with Long-Run Equilibrium: An Empirical Analysis

by

Sugata Biswas, Master of Arts
Utah State University, 1993

Major Professor: Dr. Terrence F. Glover
Department: Economics

This study investigates the linkage between long-run and short-run dynamics of exchange rate determination for the German mark/U.S. dollar quarterly rate for the period 1973-1990. Earlier investigations failed to explicitly take into account the possible nonstationarity of the data set they were using. This study continues the work performed in this area by applying modern econometric techniques to empirical tests of the Dornbusch model. In essence, this study revives the monetary model and determines if the empirical analysis using the German/U.S. case derives elements which are compatible with the monetary theory of exchange rate determination.

(92 pages)
CHAPTER I
INTRODUCTION

Background

The relationship between short-run exchange rate dynamics and macroeconomic variables has puzzled economists for a number of years. Particularly curious has been the relation among the money supply, interest rates, expected depreciation and spot exchange rate. Since the introduction of floating exchange rates in the early 1970s, exchange rates have been substantially more volatile. From a long-term point of view the most popular benchmark standard is represented by the theory of purchasing power parity (PPP). Based on the law of one price, that is, equalization of commodity prices through trade, it is postulated that a percentage change in the exchange rate equals the difference between the rates of inflation in the two countries. Within the PPP framework, the constancy of the real exchange rate arising from a monetary disturbance has been of particular importance. If the real exchange rate remains constant over time, this essentially implies monetary neutrality. Consider, for example, that following an unexpected 10% increase of the domestic money supply, the price level increases by 10%. Clearly, if the theory of PPP holds, this 10% increase in the price level will eventually cause the exchange rate to depreciate by 10%. However, in the short run there may be temporary deviation from PPP, implying the
nonneutrality of money. In moving from one equilibrium to another the exchange rate may overshoot the new long-run equilibrium value and then gradually return to it. The term "overshooting" refers to exchange rate changes in excess of some equilibrium exchange rate which may be based on purchasing power parity or some other long-run model.

An analysis of overshooting of exchange rate has important policy implications. As Levich (1985) comments:

First, exchange rate overshooting may signal that the market is inefficient and profit opportunities exist and/or some sort of government corrective action (not necessarily intervention) is required. Second, if the foreign exchange market is operating efficiently, overshooting may simply suggest that investing in foreign currency assets is somewhat riskier than is implied by simpler models. [P. 1017]

The overshooting of exchange rates beyond their equilibrium value was first theoretically developed by Dornbusch (1976) in his classic paper, "Expectations and Exchange Rate Dynamics." Much of the recent work on overshooting is based on the Dornbusch paper. Dornbusch extends the Mundell-Flemming model of the macroeconomic determinants of exchange rates.

The model developed by Dornbusch is called an asset approach to exchange rates. The exchange rate is the price of one country's money in terms of another country and is viewed as an asset price which moves to equilibrate the international demand for stocks of assets. However, differences in the adjustment speed between the goods market
and money market create a difference between the short-run and the long-run exchange rate. Frankel (1979) took one version of the asset view of the exchange rate in which rapid adjustments in capital markets were combined with slow price adjustments in goods markets. He econometrically estimated a spot rate equation for the mark/dollar rate from July 1974 to February 1978. Frankel observed the overshooting of exchange rate above its equilibrium value by an amount proportional to the real interest differential.

The Dornbusch model of overshooting was directly tested by Driskill (1981) with the U.S. dollar/Swiss franc rate for the 1973-1979 period. His empirical findings failed to reject the overshooting hypothesis. Proportionate change in exchange rate was found to be greater than the change in money supply. In a monetary model these would be the same in the long run. The response of exchange rate was found to be 2.3 percent for one percent increase in money supply. Driskill observed the path of exchange rate adjustment to be nonmonotonic.

Statement of Problem

Although the findings seem to illustrate the strength of the Dornbusch model, we are still left with an uneasy feeling regarding the validity and applicability of the conclusions reached by these empirical works. The problem is the econometric methodology used in empirically testing the Dornbusch model. Recent advances in time series
analysis have shown that economic data are generally not stationary and this may lead to spurious results. As Driskill and others empirically tested the Dornbusch model, they did not explicitly take into account the possible non-stationarity of the time series data that they were using.

Objectives

There are three main objectives of this study. They are:

A. To provide an historical perspective of exchange rate behavior and policy since the adoption of the gold standard in order to study long-run and short-run patterns which have existed under the floating-managed float era of the present period.

B. To examine the overshooting hypotheses of the Dornbusch and Driskill models and the existence of the monetary model in general using modern time series techniques.

C. To investigate the linkage between long-run and short-run dynamics of exchange rate determination for the German mark/U.S. dollar quarterly rate for the period 1973-1990.

As will be shown below, in the MLE approach to this problem, what is important is determining the $\Pi$, $\alpha$, and $\beta$ matrices. The $\Pi$ matrix contains the long-run relationships between the variables. The $\alpha$ matrix is composed of coefficients which represent the speed of the adjustment and
the $\beta$ matrix contains $r$ cointegrating vectors. These matrix components are the error correction elements of more general vector autoregression specification of the relationship of the exchange rate to macroeconomic fundamentals outlined by the monetary approach to exchange rate determination or the existence of other theories of exchange rate behavior. We will in essence be reviving the monetary model and determining if the empirical analysis using the German/U.S. case derives elements which are compatible with the monetary theory of exchange rate determination.

This study is divided into six chapters. The second chapter provides a historical perspective by surveying the ideas and major developments in the international monetary system between the late 1800s and 1973. The third chapter introduces exchange rate overshooting and its relationship with the money supply. The fourth chapter reviews Dornbusch's model and Driskill's empirical work on it. The fifth chapter reviews a selected number of topics in modern time series analysis. The sixth chapter presents the results of the empirical analysis performed here. Finally, some closing comments are included at the end.
CHAPTER II
REVIEW OF THE HISTORICAL DEVELOPMENT OF
EXCHANGE RATE REGIMES

In attempting to understand the current exchange rate behavior, it is useful to gain a historical perspective on the international monetary system, the system under which exchange rates operate. Historically, the system can be divided into roughly four periods: the gold-standard era (1870 to 1914), the interwar period (1918 to 1939), the Bretton Woods era (1945 to 1973) and the post-Bretton Woods era (1973 to present).

In looking at the various exchange-rate systems, it is important to keep in mind that the policymakers generally have two basic goals in an open economy, internal balance and external balance. Internal balance simply implies that the economy is at full employment and that the price is stable. External balance refers to not having an excessive imbalance in international payments. These two goals continue to be the basic goals of modern macroeconomic policymakers. The success they have had during the various periods has varied widely.

The Gold Standard: 1870-1914

The use of gold as a medium of exchange dates back to ancient times. Its inherent value and durability made it an...
obvious choice. However, it was not until 1819 that the use of the gold standard was legally codified with the passage of the Resumption Act by the British Parliament. The Resumption Act was so-called because it required the Bank of England to resume the practice of exchanging gold for currency notes at a fixed rate. This practice had been discontinued during the Napoleonic Wars. Perhaps more importantly the Resumption Act also repealed the barriers to exporting gold coins from Britain.

During the nineteenth century, England was the premier economic power and as such directly and indirectly influenced the economic policies of other nations at the time. After the passage of the Resumption Act, other countries followed England in adopting the gold standard in hopes of achieving similar economic success. The United States legally adopted the gold standard in 1900 with the passage of the Gold Standard Act of 1900. In reality, the U.S. had adopted the gold standard some years earlier when they pegged the paper "greenbacks" to gold in 1879. England, of course, became the center of the international financial system built on the gold standard.

During this time a central bank's primary responsibility was to maintain the official parity between its currency and gold. In order to do this the central bank needed an adequate stock of gold reserves. Thus, the external balance that policymakers sought during the gold
standard was a situation in which gold was neither gaining nor losing in the country. In aiding to achieve this end, the gold standard contained some powerful automatic mechanisms, including the price-specie-flow mechanism. The reactions of central banks to gold flows into their country provided another mechanism to help restore the balance of payments equilibrium. The practice of selling domestic assets in the light of a deficit or buying domestic assets in the light of a surplus became known as the gold standard "rules of the game." This policy increased the efficiency of the automatic adjustment process inherent in the gold standard.

Research into the behavior of banks during the time of the gold standard has shown that the "rules of the game" of the gold standard were frequently violated and governments ignored the effects of their actions on other countries. Although it may be appealing to picture smooth and automatic balance of payments adjustment, it was not the case in reality.

The gold standard does not seem to have had a significant effect on internal balance. There are several possible explanations of this lack of influence. First consider that the gold standard aimed at limiting monetary growth in the world economy and thus tried to ensure stability in the world price level, not the individual domestic price levels. National price levels did move
unpredictably with periods of inflation and deflation. A fundamental cause of internal imbalance is attributable to the subordination of internal objectives to external objectives. This bias of economic policy towards external objectives changed only after World War I as a result of the worldwide economic instability of the interwar years, 1918-1939.

The Interwar Years: 1918-1939

With the outbreak of World War I, governments financed part of their military expenditures by printing money and abandoning the gold standard. During the time of the war, this practice seemed to be the only reasonable course of action. However, after the war this policy of simply printing money to pay for governmental purchases proved to be very damaging. The celebrated case in point is the case of the German hyperinflation, during which the German price level rose by 481.5 billion percent.

After the end of World War I, the United States returned to the gold standard in 1919. Postwar global economic conditions were such that many countries desired the comparative stability of the gold standard. In 1922 a conference was held in Genoa, Italy in which a group of countries including Britain, France Italy and Japan agreed to a program calling for a general return to the gold standard and cooperation among nations in attaining both internal and external objectives. The members of the
conference realized the gold supplies were not adequate in meeting the demands for international reserves. For this reason, the Genoa Conference sanctioned a partial gold exchange standard in which smaller countries could hold the currencies of larger countries as reserves. The larger countries' reserves would consist entirely of gold.

Britain, in 1925, returned to the gold standard by pegging the pound to gold at the prewar price. This was done despite the fact that the price level was higher in 1925 than during the prewar gold standard. Winston Churchill, the Chancellor of the Exchequer at the time, argued that to do otherwise would have undermined the confidence of foreigners in the stability of Britain's financial institutions. The problem with following such a practice was that the Bank of England was forced to follow a contractionary monetary policy that contributed to severe unemployment.

Keynes and others predicted the depression in Britain which followed the return to the gold standard. In effect, the return to the gold standard was a revaluation of the pound against foreign currencies and this led away demand for British-made products. This depression began to weaken London's role as the world's leading financial center. Many smaller countries held British pounds in reserve but England's economic troubles did not inspire any confidence. Britain was forced to abandon the gold standard in 1931.
after the bank failures following the Great Depression and the conversion of pounds to gold by foreigners who had lost confidence in the Britain's commitment to maintain its currency's value.

As the depression continued in the 1930s, many countries abandoned the gold standard. The United States left the gold standard in 1933 and returned to it in 1934, having raised the price of gold. Several countries also competitively devalued their currency. This induced domestic unemployment only in as much as worldwide monetary expansion was encouraged by higher nominal prices of gold.

In an attempt to alleviate the burdens of the depression, each country began to follow practices that restricted international trade and payments. Each individual country attempted to discourage imports and keep demand at home. An example of such practices was the Smoot-Hawley tariff imposed by the United States in 1930. This tariff resulted in increasing unemployment abroad and encouraged retaliatory measures by foreigners. These trade barriers along with deflation in the industrial economies of America and Europe led to many defaults of international loans. Increasingly, the world economy was disintegrating into autarkic national units. The problems in the world markets continued until the beginning of World War II in 1939.
Many countries, during this interwar period, chose to curtail the possibility of significant external imbalance by curbing their trade among other nations. Following this policy, of course, crippled the world and the domestic economies since gains from trade were reduced. All countries would have been better off with less restrictive international trade. This understanding helped to shape the design of the postwar international monetary system.

The Bretton Woods System: 1945-1973

As the second world war was coming to a close, economists and politicians from the United States, Britain and their major allies gathered to plan a new global economic order. The conference met in July 1944 in Bretton Woods, New Hampshire and was headed by British economist John M. Keynes and American diplomat H. D. White. The conference led an agreement which led to the formation of the International Monetary Fund (IMF), the World Bank, and the Bretton Woods exchange-rate system, known generally as the Bretton Woods system.

The Bretton Woods system was a framework designed to manage exchange rates. This system was to replace the gold standard by establishing a parity for each currency in terms of both the U.S. dollar and gold. The dollar was considered to be the reserve currency and as such it was pegged only to gold. Other currencies were valued in terms of both the dollar and gold and thus a set of exchange rates among
currencies was fixed by international agreement. If a currency moved too far away from its "fundamental" value, then the parity could be adjusted. This ability to adjust exchange rates was the basic difference between the Bretton Woods system and the gold standard.

It was hoped that exchange rate changes would be worked out cooperatively among the nations. The Bretton Woods system was a fixed but adjustable system designed to capture the best of two worlds, i.e., the stability of the gold standard and the flexibility of floating exchange rates.

At the time of conception, the Bretton Woods system appeared to be without major flaws. However, what made the Bretton Woods system flexible also brought about balance of payments crises throughout the 1960s and 1970s for nations other than the United States. The problem lay in the IMF's ability to devalue or revalue a currency. For example, a country with a persistent current-account deficit could be suspected of being in "fundamental disequilibrium" and thus ready for a devaluation of its currency. Such action created a problem for anyone holding that country's currency. Once the currency was devalued, then anyone holding that country's currency would stand to suffer a loss. If Britain ran a persistent current account deficit, then holders of pounds would shift their wealth away from pounds and towards other currencies. In turn, the Bank of England would have to buy pounds to hold the pound's
exchange rate fixed. If the loss of foreign reserves were large enough, then it might force a devaluation by leaving the Bank of England without enough reserves to prop up the exchange rate. Similarly, there was a problem for countries which ran current account surpluses.

This balance of payments problem reached crisis proportions in the 1960s and 1970s. Although this problem was severe, it was not alone in bringing about the demise of the Bretton Woods system. The culpability rests mainly with the loss of confidence in United States' ability to pay out gold for its dollars held by foreigners.

In 1960 economist Robert Triffin called attention to a fundamental long-run problem. He showed that over time the amount of dollars held by foreigners would exceed the stock of gold held by the United States. This might bring about a crisis in confidence because central banks may be unwilling to accumulate any more dollars and could actually bring the entire system down by attempting to convert all assets in dollars into gold. Although the details were slightly different, in essence this is what had happened. Dollar holdings went from nearly zero in 1945 to $50 billion in the early 1970s. Central banks realized that the dollar would have to be devalued in order for the United States to meet its foreign obligations. Since the United States was the reserve currency, devaluing it was not a simple task. The dollar could be devalued only if foreign governments agreed
to peg their currencies against the dollar at new rates. The problem was that many of the United States' trading partners were hesitant to do that. On August 15, 1971, President Richard M. Nixon forced the entire issue by executing the following measures.

First, he severed the link between the dollar and gold by announcing that the United States would no longer automatically sell gold to foreign central banks for dollars. Second, he announced a 10% tax on all imports into the U.S., suggesting that it would remain in effect until the trading partners agreed to revalue their currencies against the dollar. He also introduced some domestic stabilization measures designed to reduce the U.S. inflation. The trading partners did agree to the devaluation in December of 1971. Later a further devaluation of the dollar took place but still speculation against the dollar continued. By 1973 the speculative capital movements became unmanageable. At the time a temporary response was to allow the currencies of the industrialized nations to float against the dollar. However, this temporary solution adopted on March 1973 became permanent, thus ending the period of fixed exchange rates and ushering in the currently turbulent period of managed flexible exchange rates.

The switch to floating exchange rates and the consequent volatility of its behavior raises some questions
concerning the possible adverse effects that the volatility may have on the world economy. Among the concerns is the belief that disturbances in the home money market could be more disruptive under a floating system than under a fixed system. This concern has led to a number of studies of the impacts of unexpected movements in the money supply and exchange rate behavior. Some questions remain unanswered at this point.

Exchange rate behavior has been explained in recent years by primarily using the monetary model for the explanation of the variation, and it has been assumed that there is a long-run equilibrium relationship between the exchange rate and monetary movements. Most studies either assume that there is a relationship between exchange rate variation and the macroeconomic fundamental, or have used basic econometric analysis to suggest that such a relationship exists without inspection of stationarity properties in the data. The next five chapters of this study report on an attempt to determine this underlying relationship, as well as test the efficacy of the monetary model as an explanation of the variations in the exchange rate. Tests of stationarity are also made in U.S. and German data as a case study.
CHAPTER III

EXCHANGE RATE BEHAVIOR AND MACROECONOMIC VARIABLES

As the study of exchange rate behavior developed, some basic relationships between the exchange rate and macroeconomic variables began to emerge. These relationships provide the insight necessary to more fully develop theories on exchange rate dynamics and, as a precursor to our study of the Dornbusch model, this chapter reviews some of these basic relationships.

This review is divided into several sections covering the basic concepts of exchange rates, overshooting, purchasing power parity, etc. These concepts are extensively used throughout the remainder of this study, so the review provides a useful foundation.

Exchange Rates and Their Determination

Simply stated, the exchange rate is the price of one currency in terms of another. The behavior of exchange rates varied widely under different exchange rate arrangements. Under the current system of managed floating exchange rates, the exchange rate of a country is determined on the foreign-exchange market. The foreign-exchange market is in equilibrium when deposits of all currencies offer the same expected rate of return.
When the expected returns on deposits of any two currencies are equal, the returns meet interest parity condition. The interest parity condition can be symbolically represented in the following:

\[ R_s = R_{DM} + \left( E_{\$/DM}^{e} - E_{\$/DM} \right) / E_{\$/DM} \]  

where
- \( R_s \) = current annual interest rate on dollar deposits
- \( R_{DM} \) = current annual interest rate on DM deposits
- \( E_{\$/DM} \) = current price of DM in terms of dollars
- \( E_{\$/DM}^{e} \) = dollar/DM exchange rate expected to prevail at the end of the year.

The graphical presentation of the asset view of the determination of exchange rate is based on Krugman and Obstfeld (1991). Figure 1 shows the uncovered interest-parity condition of equation 1 which holds in equilibrium.

The right hand side of equation 1 represents the expected return on DM deposits. It is apparent that there is an inverse relation between today's dollar/DM exchange rate decline and the expected return. Thus, it accounts for the negative slope of the curve representing the expected return on DM deposits. In figure 1 the equilibrium is shown at point 1 and this equilibrium satisfies the equilibrium condition given by equation 1.

The equilibrium in figure 1 is stable. Suppose that we are at point two; in this situation the expected return on DM deposits is lower than the return on dollar deposits.
Anyone holding DM deposits will wish to sell them for dollar deposits and this will cause the dollar/DM exchange rate to fall toward the equilibrium exchange rate. The exchange rate will continue to fall until it has reached the equilibrium exchange rate because at this point there is no incentive for the central bank to try to sell DM for dollars because the expected rate of return on DM is equal to the rate of return on dollar deposits.

The effect that a change in the rate of return on dollar deposits has on the exchange rate is shown in figure 2. A decline in the rate of return in dollar terms from R1 to R2 has the effect of increasing the exchange rate from E1.
Fig. 2 -- Effect of a rise in the dollar interest rate to E2. Intuitively, this seems to be clear since a decline in the domestic rate of return will make foreign investment more attractive. Investors will want to invest in foreign-held stocks and bonds and thus the demand for foreign currency will go up, causing the dollar/DM exchange rate to rise.

**Interest Rate Determination**

The interaction between the money supply and money demand in the domestic money market will determine the equilibrium interest rate. The equilibrium condition is given by
Figure 3 graphically demonstrates this equilibrium. The stability of this equilibrium can be determined if we consider what would happen if there were an initial excess money supply or excess money demand. Suppose that initially there were an excess supply of money, represented by point 2. In this case the amount of money supplied is greater than the demand for money for a given interest rate. This situation will cause the interest rate to drop until the demand for money is equal to the supply of money.

\[ M^s = M^d. \]
The effect that a change in the real money supply has on the interest rate is shown in figure 4. An increase in the real money supply causes the interest rate to fall. This is as expected because the initial increase in the money supply will cause the money supply to be greater than the amount of money demanded, so the interest rate will fall in order to return to equilibrium.

Fig. 4 -- Effect of a rise in the money supply on the interest rate for a given price level and real income level
Money, Interest Rate and the Exchange Rate

The discussion above clearly implies that there is a link between the real money supply, interest rates and the exchange rate. This relationship is graphically demonstrated in figure 5. We can see that for a given level of real money supply there is a corresponding equilibrium in the foreign exchange market. Note that the link is the interest rate.

Fig. 5 -- Simultaneous equilibrium in the U.S. money market and the foreign-exchange market
The effect that a change in the real money supply has on the equilibrium exchange rate is graphically shown in figure 6. When the real money supply increases in the U.S. from \((M/P)_1\) to \((M/P)_2\), the domestic interest rate falls from \(R_1\) to \(R_2\). This decline in the domestic interest rate will cause capital outflow from the U.S. and thereby depreciate the dollar against the DM. The equilibrium is reestablished at point 2' in the foreign exchange market.

Fig. 6 -- Effect on the dollar/DM exchange rate and dollar interest rate of an increase in the U.S. money supply
Permanent Changes in the Money Supply and the Exchange Rate

Figure 7 shows both the short-run and the long-run effect of a permanent increase in the money supply. Initially all variables are at their long-run levels. Then there is a permanent increase in the money supply from M1 to M2. In the short run this increase in the nominal money supply will cause an increase in the real money supply from \( \frac{M1}{P1} \) to \( \frac{M2}{P1} \).

![Diagram showing short-run and long-run effects]

Fig. 7 -- Short-run and long-run effects of an increase in the U.S. money supply
This increase in the real money supply causes a decrease in the domestic interest rate from R1 to R2. It can be shown that since this is a permanent increase in the money supply, the exchange rate expectations will also increase because people will expect the price of all goods to go up, including the exchange rate, which is the dollar price of DM. This will cause the expected dollar return on DM deposits to shift to the right. Thus the decrease in the domestic interest rate from R1 to R2 will cause the exchange rate to increase from E1 to E2. Note that the dollar depreciation is greater than it would have been had the expected future dollar/DM exchange rate stayed the same. If it had not changed, the new equilibrium would have been at 3' instead of 2'.

The long-run adjustments are shown in figure 7-b. The price level begins to rise from P1 to P2. This gradual rise in the price level is translated into a decrease in the real money supply from (M2/P1) to (M2/P2). The decrease in the real money supply causes an increase in the domestic interest rate. Assuming that expectations do not change further, then the increase in the U.S. interest rate will cause the exchange rate to adjust along the downward-sloping schedule, from point 2 to point 4, defining the dollar return on DM deposits. Note that although the price level has returned close to its original value, the new equilibrium exchange rate will still be higher than the
original value since the expectations for DM deposits have changed. As will be shown below, Dornbusch assumes that the expectations do not change but that the price level does not rise sufficiently to make the interest rate return to its original value.

**Exchange Rate Overshooting**

The discussion above describes the phenomenon of exchange-rate overshooting and figure 8 graphically represents this phenomenon. The exchange rate is said to overshoot if its immediate response to any disturbance is greater than its long run response. As was shown earlier, this is what happens when there is an unexpected increase in

![Diagram of economic variables](image)

*Fig. 8 -- Time paths of U.S. economic variables after a permanent increase in the U.S. money supply*
the money supply. The top left corner shows the effect of a sudden increase in the money supply from M1 to M2. In turn the interest rate drops from R1 to R2 and the exchange rate rises from E1 to E2. All of this happens in the short run. In the long run, the price level gradually adjusts from P1 to P2, causing the rise in the dollar interest rate from R2 to R1 and the gradual decrease in the exchange rate from E2 to E3. Thus, it is clear that the exchange rate overshoots in the short run as a direct consequence of the short run rigidity of the price level.

Long Run Exchange Rates and Purchasing Power Parity

In the above discussion the phenomenon of overshooting was described in terms relative to the long run. However, the question of what determines the long-run exchange rate is relevant. One explanation of the long-run determination of exchange rates is given by the theory of purchasing power parity (PPP). In spite of much controversy about the validity of PPP (Dornbusch, 1990), the theory sheds light on important factors determining movements in exchange rates. Simply put, PPP states that the exchange rate between two countries is equal to the ratio of the countries' price levels. In symbols, PPP predicts

$$E_{s/DM} = \frac{P_{US}}{P_{g}}$$

Rearranging the above equation we get:

$$P_{US} = (E_{s/DM})(P_{g}).$$
where \( P_{US} \) = the dollar price of a basket of goods in the U.S.
\( P_g \) = the DM price of the same basket.

This is an alternative interpretation of PPP. This states that all countries' price levels are equal when measured in terms of the same currency.

Combining the framework of the money supply and money demand and the theory of PPP leads to an approach in determining how the exchange rate interacts with the monetary factors. This approach is called the monetary approach to the exchange rate. This approach is considered to be in the long run because it does not allow for price rigidities.

The fundamental equation of the monetary approach is
\[
E_{S/DM} = \frac{M^{S}_{US}}{M^{S}_{G}} \cdot \lambda(R_s - R_{DM}, Y_G/Y_{US})
\]
where \( \lambda(R_s - R_{DM}, Y_G/Y_{US}) \) is relative aggregate real money demand in Germany compared with the United States. The conclusions of the monetary approach are that (1) the foreign-exchange value of a country's currency moves in proportion to its money supply in the long run and (2) a rise in the country's interest rate depreciates its currency by lowering the real demand for its money.

Dornbusch followed an approach similar to this when he developed his model. This study follows the work of Dornbusch and Driskill. The next section reviews the models introduced by Dornbusch and Driskill.
CHAPTER IV

A REVIEW OF THE DORNBUSCH AND DRISKILL MODELS

When the exchange rate system turned from a fixed to a flexible system, there was much concern about the dynamic behavior of the exchange rate. Much of the discussion centered on the idea of overshooting. Rudiger Dornbusch's pioneering work, "Expectations and Exchange Rate Dynamics" (1976), led the study in this area. Dornbusch concluded that

...along that [the perfect foresight] path a monetary expansion causes the exchange rate to depreciate. An initial overshooting of exchange rates is shown to derive from the differential adjustment speed of markets. [P. 1161]

It is the short-run rigidity of the price level in the goods market that causes the overshooting. At the time Dornbusch did not proceed to empirically validate the conclusions of his model. This provided the opportunity for others, including Driskill (1981), to do so. Using Swiss/U.S. data from the period 1973-79, Driskill rejected the Dornbusch model but confirmed the overshooting phenomenon. The following is a brief review of the Dornbusch model, Driskill's estimation of that model and the stock/flow model.
The Dornbusch Model

The Dornbusch model has essentially the following three basic parts: a money market equilibrium, a price-level adjustment equation and a dual assumption of uncovered-interest-arbitrage specification and exchange rate expectations.

Assumptions:
1. Small country which faces a given exchange rate.
2. Capital mobility exists.
3. World price of imports given.
4. Domestic output is an imperfect substitute for imports.
5. Assets denominated in terms of domestic and foreign currency are assumed to be perfect substitutes.

Capital Mobility and Expectations

From the interest parity conditions:
\[ R_d = r_f + \left[ (E^e - E)/E \right] \]
\[ r = r^* + x \]

where:
- \( r \) = domestic interest rate
- \( r^* \) = given world rate of interest
- \( x \) = expected rate of depreciation of the domestic currency.

It is assumed that incipient capital flows will ensure that equation (1) holds all of the time. Equation (2) is a statement of expectations formation.

\[ x = \theta (\bar{E} - e) \]

where:
- \( \bar{E} \) = log of long-run exchange rate
\[ e = \log \text{ of current exchange rate} \]
\[ \theta = \text{adjustment coefficient.} \]

**The Money Market**

The demand for real money balances is a function of domestic interest rate and real income. In equilibrium, demand for real money balances is equal to the real money supply. Assuming a conventional demand for money, the demand for real money balances can be written in the following form:

\[ \text{Demand for real money balances} = Y^\phi \cdot e^{-\lambda r} \]
\[ \text{real money supply} = M/P \]

Therefore, in equilibrium:

\[ Y^\phi \cdot e^{-\lambda r} = M/P \]

We can linearize the above equation by taking the log of both sides.

\[ \phi y - \lambda r = m - p \]

where:
\[ y = \log \text{ of real income} \]
\[ m = \log \text{ of nominal quantity of money} \]
\[ p = \log \text{ of the domestic price level} \]

OR

\[ -\lambda r + \phi y = m - p. \] (3)

Replacing \( r \) from equation (1) to equation (3) we get

\[ -\lambda (r^* + x) + \phi y = m - p \]
\[ -\lambda (r^*) - \lambda (x) + \phi y = m - p. \]
Replacing \( x \) from equation (2)

\[-\lambda(r^*) - \lambda[\theta(\bar{e} - e)] + \phi y = m - p\]

OR

\[p - m = -\phi y + \lambda(r^*) + \lambda[\theta(\bar{e} - e)].\]  \( (4) \)

By applying simple algebraic manipulations to equation (4) we get the following result:

\[e = -(1/\lambda\theta)[p - m + \phi y - \lambda r^*] + \bar{e}\]

\[= -(1/\lambda\theta)(p - m) - (\phi/\lambda\theta)y + (1/\theta)r^* + \bar{e}\]

\[= \bar{e} + (1/\lambda\theta)(m + \lambda r^* - \phi y) - (1/\lambda\theta)p.\]  \( (5) \)

In the long run, from equation (3) we get the following solution for the price level:

\[p = m + \lambda r^* - \phi y\]  \( (6) \)

where: \( r^* \) is present because of interest parity

\[p = \log \text{ of long-run price level.}\]

Thus, considering equations (5) and (6), we conclude the following:

\[e = \bar{e} + (1/\lambda\theta)(p - (1/\lambda\theta)p\]

\[= \bar{e} + (1/\lambda\theta)(p - p)\]

\[= \bar{e} - (1/\lambda\theta)(p - p).\]  \( (7) \)

Clearly, equation (7) determines the current spot exchange rate as a function of the current level of prices when the long run exchange rate and price level are given. Thus, it is through the money market that we understand why there are fluctuations in the spot exchange rate when the current price level changes. However, to understand
movements of the price level, we need to look into the goods market.

The Goods Market

The goods market will be in equilibrium when the aggregate demand is equal to the aggregate supply. In this simple model the government is not being considered and so aggregate demand will have the following three components: C, I and (X-M). C is determined from y, which is given. In the long run, since \( r = r^* \), I can also be determined. This leaves net exports, X-M. Net exports depends on \( (E \cdot P^*)/P \) or \( \ln E - \ln P^* - \ln P \). Normalize by assuming \( P^* = 1 \) and so net exports depend upon the exchange rate price differential, \( e-p \). In the long run \( p \) is determined from the quantity theory. Thus, in the long run \( p = p \) and hence net exports is a function of \( e-p \). The burden of adjustment falls on \( e \), given \( p \) is fixed. Keeping this in mind, consider the demand function for domestic output. The function is assumed to have the following form:

\[
D = U \cdot \frac{E}{P} \cdot Y \cdot e^{-\sigma r}.
\]

In the demand function \( U \) is a sum of all the constant terms, that is, it is a shift parameter. Since \( P^* = 1 \), taking the log of both sides of the above equation will lead to the following equation:

\[
d = \mu + \delta(e-p) + \gamma Y - \sigma r. \tag{8}
\]

Equation (8) mathematically denotes the earlier discussion, that is, that net exports depend upon the
exchange rate price differential, e-p, consumer consumption depends upon income, y, and that investment depends upon the domestic interest rate. The rate of change in the price of domestic goods is a function of the log of excess demand. Mathematically, the rate of change of the price level may be written as:

\[ p = \frac{dp}{p} \frac{1}{dt} = \Pi(\ln \text{of excess demand}) \]
\[ = \Pi(\ln D - \ln Y) \]
\[ = \Pi(d - y) \]
\[ = \Pi[\mu + \delta(e - p) + \gamma y - \sigma r - y] \]
\[ = \Pi[\mu + \delta(e - p) + (\gamma - 1)y - \sigma r]. \] (9)

Setting the rate of change equal to zero in the long run and solving for \( \bar{e} \) results in:

\[ p = \Pi[\mu + \delta(e - p) + (\gamma - 1)y - \sigma r] \]
\[ 0 = \Pi[\mu + \delta(\bar{e} - p) + (\gamma - 1)y - \sigma r^*] \]
\[ \delta(\bar{e} - p) = \sigma r^* - \mu - (\gamma - 1)y \]
\[ (\bar{e} - p) = \frac{[\sigma r^* - \mu - (\gamma - 1)y]}{\delta} \]
\[ \bar{e} = \left\{ \left[ \frac{[\sigma r^* - \mu - (\gamma - 1)y]}{\delta} \right] + p \right\} \] (10)

where:

- \( \bar{e} \) is the log of long-run equilibrium exchange rate
- \( p \) is the log of the long-run price level
- \( r^* \) is the log of the world interest rate.

From equation (10) it is apparent that not only does the long-run exchange rate depend with the conventional homogeneity properties on monetary variables, but also on real variables.
Equation (9) can be simplified by using equations (1), (2), (7) and (10). The steps of the simplification and the result are shown below.

\[
p = \Pi[\mu + \delta(e-p) + (\gamma-1)y - \sigma r]
\]

\[
= \Pi[\mu + \delta(e-p) + (\gamma-1)y - \sigma_t(\bar{e}-e) + \sigma^*]
\]

\[
= \Pi[\mu + \delta(e-p) + (\gamma-1)y - \sigma_t(\bar{e}-e) - \sigma^*]
\]

\[
= \Pi[\mu + (\gamma-1)y - \sigma^* + \delta(e-p) - (\sigma/\lambda)(p-p)]
\]

\[
= -\Pi[\sigma^* - (\gamma-1)y - \mu - \delta(e-p) + (\sigma/\lambda)(p-p)]
\]

\[
= -\Pi[\delta(\bar{e}-p) - \delta(e-p) + (\sigma/\lambda)(p-p)]
\]

\[
= -\Pi[-\delta(e-\bar{e}) + \delta(p-p) + (\sigma/\lambda)(p-p)]
\]

\[
= -\Pi[\delta(\bar{e}-p) - \delta(e-p) + (\sigma/\lambda)(p-p)]
\]

\[
= -\Pi[-\delta(-(1/\lambda\theta)(p-p)] + \delta(p-p) + (\sigma/\lambda)(p-p)]
\]

\[
= -\Pi[(\delta/\lambda\theta)(p-p)] + \delta(p-p) + (\sigma/\lambda)(p-p)]
\]

\[
= -\Pi[(\delta/\lambda\theta) + \delta + (\sigma/\lambda)(p-p)]
\]

\[
= -\Pi[(\delta/\lambda\theta) + \delta + (\sigma/\lambda)(p-p)]
\]

\[
= -\Pi[\{(\delta+\sigma\theta)/\lambda\theta) + \delta\}(p-p)]
\]

\[
= -v(p-p)
\]

where: \( v = \Pi[(\delta+\sigma\theta)/\lambda\theta) + \delta]. \)

Equation (11) tells us the path of the price movement.

The price adjustment equation:

\[
p(t) = p + (p_0 - p)e^{-vt}.
\]

The time path of the exchange rate:

\[
e(t) = \bar{e} + (e_0-\bar{e})e^{-vt}.
\]

(11)

(12)

(13)
Driskill's Estimation

Driskill (1981) empirically investigated the Dornbusch model and a stock/flow model with Swiss/U.S. data over the period 1973-77. In so doing he developed empirical estimations of both models. Driskill's approach in developing the empirical estimation of the Dornbusch model was to develop separately each of the three parts: (1) the money market equilibrium, (2) the price-level adjustment equation, and (3) the dual assumption of uncovered-interest-arbitrage specification and exchange rate expectations.

The Money Market Equilibrium

By assuming that the domestic and foreign countries have identical structural parameters, the money market equilibrium can be written as:

\[(m_t)^d = m_t = p_t - \lambda r_t + \phi y_t + v_t \]  

where: \( v_t \) is a serially uncorrelated random variable with zero mean and variance \( \sigma_v^2 \).

Price Level Adjustment Equation

In the goods market, relative demand for output is a function of relative real income, relative interest rates and relative prices. Equation (8) gives the following

\[ d_t = \mu + \delta (e_t - p_t) + \gamma y_t - \sigma r_t. \]  

By equation (9) we know that the relative rate of change in the price of domestic goods is proportional to the log of excess demand:

\[ p_{t+1} - p_t = \Pi [d - y_t]. \]
From equations (14), (8) and (9) it is simple to derive the following relative price equation:

\[ P_t = a_0 Y_{t-1} + a_1 p_{t-1} + a_2 m_{t-1} + a_3 e_{t-1} \]  

(15)

where:

\[ a_0 = \Pi (1 - \gamma) + \phi/\lambda \]
\[ a_1 = 1 - (\Pi \sigma)/\lambda - \Pi \delta \]
\[ a_2 = (\Pi \sigma)/\lambda \]
\[ a_3 = \Pi \delta. \]

**Uncovered Interest Arbitrage and Exchange Rate Expectations**

The final part of the Dornbusch model is the assumptions of uncovered interest arbitrage and exchange rate expectations. The uncovered interest arbitrage essentially refers to the interest parity conditions and can be written as:

\[ r_t - x_t = 0 \]  

(16)

where:  
\[ x_t = \text{the expected change in } e \text{ from } t \text{ to } t+1. \]

Assuming that relative money supply follows a random walk, we can make the following statement of expectations formation:

\[ x_t = \theta (m_t - e_t) + k \]  

(17)

where:  
\[ 0 < \theta < 1 \text{ and } k \text{ is a constant.} \]

Combining the equations (14), (15), (16) and (17) we can derive the following reduced-form equation:

\[ e_t = \Pi_0 + \Pi_1 e_{t-1} + \Pi_2 m_t + \Pi_3 m_{t-1} + \Pi_4 p_{t-1} + \Pi_5 y_t + \Pi_6 Y_{t-1} + \Pi_7 z_t \]  

(18)
where: \( z_t \) is a first order serially correlated random variable.

Also, all the variables are in relative terms. Finally, the following constraints on the coefficients must hold:

\[ \Sigma_{i=1}^4 \Pi_i = 1 \quad \Pi_3 < 0 \quad \Pi_6 < 0 \]
\[ \Pi_1 < 0 \quad \Pi_4 < 0 \]
\[ \Pi_2 > 1 \quad \Pi_5 < 0 \]

The constraint on the sum of the first four coefficients implies that purchasing power parity holds in the long run. The constraint that \( \Pi_2 > 1 \) implies that there must be short-run overshooting.

**The Stock/Flow Model**

The stock/flow model is developed by generalizing the Dornbusch model to allow for imperfect capital mobility. This is done by specifying that a net demand for foreign assets as a linear function of the expected net yield.

\[ B_t = n(x_t - r_t), \quad n > 0. \tag{19} \]

Also, trade-balance is specified as a linear function of the log of relative prices and the log of relative real incomes.

\[ T_t = a(e_t - p_t) - \beta y_t + u_t, \quad a, \beta > 0, \tag{20} \]

where \( u_t \) is white noise. Finally, under a market-clearing situation in the foreign-exchange market, net capital flows equal net trade flows plus all other autonomous flows which are assumed to be constant.

\[ \Delta B_t = T_t + A_t. \tag{21} \]

Replacing equation (6) in the Dornbusch model by equation
(21), it possible to derive the following reduced-form exchange rate equation:
\[ e_t = \Pi_0 + \Pi_1' e_{t-1} + \Pi_2' m_t + \Pi_3' m_{t-1} + \Pi_4' p_{t-1} + \Pi_5' y_t \]
\[ + \Pi_6' y_{t-1} + \Pi_7' z_t \]  
(22)
where: \( z_t \) is a first order serially correlated random variable.

The following constraints on the coefficients must hold:
\[ \sum_{i=1}^{4} \Pi_i' = 1 \quad \Pi_3' <> 0 \quad \Pi_6' <> 0 \]
\[ \Pi_1' < 1 \quad \Pi_4' > 0 \]
\[ \Pi_2' > 0 \quad \Pi_5' <> 0 \]

When attempting to empirically estimate the reduced form equation, Driskill slightly changed it to accommodate a few problems. First, he dropped the income variables \( y_t \) and \( y_{t-1} \) because the proxies used did not show significant coefficients, and taking them out did not affect the remaining coefficients. Second, two dummy variables were added. The first is OIL, which accounted for the attractiveness of dollar-denominated assets following the announcement of the oil embargo and cuts in Arab oil production. This dummy variable took a value of one for the periods December-January-February (1973-74) and zero for all other periods. The second dummy variable is SEAS. This variable took a value of one during every December-January-February period and zero for all other periods. This accounted for the high end-of-the-year demand for Swiss francs by Swiss firms for the year-end "window dressing" (adjustments by the Swiss banks) of their financial
The empirical work resulted in the following:

\[ e_t = -2.22 + .43e_{t-1} + 2.37m_t - 2.45m_{t-1} \]
\[ + .93p_{t-1} + .15OIL - .06SEAS \]
\[ R^2(\text{adj}) = .99 \]

The signs of the coefficients verify overshooting but are inconsistent with the Dornbusch model and consistent with the stock/flow model.
CHAPTER V
METHODOLOGY

The work done by Driskill and others seems to empirically validate PPP for the long run and the overshooting phenomenon for the short run. However, the methodology used may have caused problems that could produce misleading conclusions. In his work Driskill assumed that there was univariate causation from money supply to exchange rates. That is, it was assumed that money supply affects the exchange rates but that monetary policy is not affected by the exchange rates. This may or may not be the case. Also, Driskill did not directly address the issue of stationarity of univariate time series. In the 1980s the issue of whether a time series is stationary or not attracted much attention. Recent studies indicate that most macroeconomic data are not stationary. The implication is that it is important to test for nonstationarity before estimating any regression equation. As Kennedy (1992) comments:

[The data is] in fact not stationary, and that this could lead to serious problems with traditional statistics such as $R^2$, DW and the t statistic. [P. 247]

Clearly, the result of using such data could lead to inaccurate or entirely false results.

Driskill also did not address similar issues in a multivariate concept where cointegration plays an important
role. The concept of cointegration is central in understanding if there exists a long-run relation among the trends in economic variables. The cointegrating regression and an error correction model are indeed important to integrate short-run dynamics with long-run equilibrium. These are the issues that this study addresses. By correcting for nonstationarity in the data set and testing for cointegration by using an MLE approach, this study will reexamine the previous conclusions regarding exchange rate behavior.

Before proceeding further, it will be useful to review the following topics in time series analysis: unit roots, cointegration, cointegrating vectors, the Engle-Granger two-step approach and Johansen's approach to integration. The article by Dickey, Jansen and Thornton (1991) has been used extensively in writing section on cointegration. The ideas presented here will be used throughout the remainder of the study.

Unit Roots

Suppose we have the following equation:

\[ x_t = \alpha x_{t-1} + e_t. \]  

(1)

The term unit roots refers to the value of \( \alpha \). If \( \alpha \) is equal to one, then the time series, \( x_t \), is said to have unit roots and is generated by a random walk stochastic process. In this type of process, the mean and variance change with time. Thus, by definition, the process is nonstationary in
levels but its first difference is stationary.

There are significant implications to a time series depending on the value of $\alpha$. If $\alpha$ is equal to one, then the series is said to have unit roots and the effect of a shock on this series is permanent. However, if $|\alpha| < 1$, then the effects of a shock diminish over time.

There are a number of tests which can be performed to test for unit roots. The most well known of these tests is the Dickey-Fuller (DF) test. The DF tests are based on the assumption that the disturbance terms are white noise errors and test the hypothesis $\alpha = 1$. There are three test statistics.

$$K(1) = T(a - 1) \quad t(1) = (a-1)/SE(a) \quad F(0,1)$$

where $a$ is the OLS estimate of $\alpha$. These three test statistics do not have the standard normal $t$ and $F$ distributions. The critical values for $K(1)$ and $t(1)$ can be found in Fuller (1976) and for $F(0,1)$ in Dickey and Fuller (1981). The null hypothesis is that the time series is nonstationary.

Cointegration

The term cointegration refers to a minimum of two time series variables. The two are said to be cointegrated if one or more linear combinations of these variables is stationary even though individually they are not. Suppose that $y_t$ is integrated of order one and $x_t$ is integrated of order one. Then $x_t$ and $y_t$ are said to cointegrated if there
exists a $\theta$ such that $y_t - \theta x_t$ is integrated of order zero. The implication is that the regression $y_t = \theta x_t + u_t \quad (2)$ has economic meaning because the two time series do not drift away from each other over time. Thus, there is a long-run equilibrium relationship between them. A lack of cointegration between two variables would suggest that there is no long-term link between the variables.

As was mentioned earlier, more than two time series can be considered and in such situations, more than one stable linear combination can exist. In the following multivariate AR(1) representation

$$Y_t = aY_{t-1} + e_t \quad (3)$$

where $Y_t$ is an (nx1) vector and is $Z_t - \mu$, where $Z_t$ is a vector of economic time series variables and $\mu$ is the vector of the means of $Z$. $A$ is an (nxn) matrix and $e_t$ is a vector of independent random disturbances, which are stationary about zero. The possibility of $k$ cointegrating vectors means there exists a (kxn) matrix $\theta'$, of rank $k$, such that $\theta'Y_t$ is stationary in the sense that it is mean reverting.

In attempting to test for cointegration there are a variety of tests that one can perform. In the next three subsections, three approaches are reviewed. The first, the Engle-Granger two step approach, is confined to the case of two time series that are integrated of order one (I(1)). The second describes the general approach which can be applied to the multivariate case. The third approach
describes the slightly more complicated Johansen's approach to the multivariate case.

Testing for Cointegration

The Engle-Granger Approach

This approach is concerned with testing for cointegration between a pair of series which are I(1). In the following regression model

\[ y_t = \theta x_t + u_t \] (4)

where \( u_t \) is I(0) and \( y_t \) and \( x_t \) are integrated of order one. It is important that the two are of order one; otherwise, there is no possibility that the two series are cointegrated. Thus, the first step in this approach is to determine the order of integration of the two series by performing unit root tests. One way would be to apply the Dickey-Fuller test. Suppose that both \( x_t \) and \( y_t \) are proved to be integrated of order one by applying the Dickey-Fuller test. The next step is to test for cointegration. Granger (1986) suggests estimating (4) by ordinary least squares. The residuals obtained from the estimated equation (4) are subjected to the Dickey-Fuller test or some other tests. As Maddala (1992) suggests, this amounts to testing hypothesis \( p=1 \) in

\[ U_t = pU_{t-1} + e_t. \] (5)

The null hypothesis is

\[ H_0: U_t \text{ is I(1)}. \]
What the null hypothesis says is that $U_t$ is integrated of order one, i.e., $y_t$ and $x_t$ are not cointegrated. If $y_t$ and $x_t$ are cointegrated, that is, if there exists a long-run equilibrium relation between the two time series, then $U_t$ is $I(0)$. All these steps imply that $y_t$ is $I(1)$ and $x_t$ is $I(1)$. We want to see that $U_t$ is not $I(1)$.

Suppose that the unit root test shows that both $x_t$ and $y_t$ are $I(1)$ and $x_t$ and $y_t$ are also cointegrated. Granger (1986) and Engle and Granger (1987) have proved that there always exists a generating mechanism that yields what is known as the "error-correcting" model (ECM):

$$\Delta y_t = \alpha \Delta x_t + \lambda (y_t - \delta x_t) + \nu_t.$$  \hspace{1cm} (6)

$\Delta y_t$ and $\Delta x_t$ are changes in $y$ and $x$, respectively. $(y_t - \delta x_t)$ indicates the extent of disequilibrium in the past period. The term $(y_t - \delta x_t)$ is called error correction term since it is a measure of the current "error" or discrepancy in achieving long-run equilibrium. In ECM equation (6), $\Delta y_t$ and $\Delta x_t$ are differenced variables while the error-correction component is measured in terms of level variables. As Kennedy (1992) comments:

This is what is supposed to give it an edge over ARIMA models, since in ARIMA models the variables are all differenced, with one use made of the long run information provided by the levels data. [P. 252]

In the Box-Jenkins approach the nonstationarity is purged by differencing. But in the process valuable information about the long-run equilibrium relation is lost.
The ECM approach uses this information by mixing differenced and levels data. Questions concerning the legitimacy of having these two different types of variables appearing in the same equation are resolved by the cointegration approach.

If the unit root test shows that both time series are of the same order, then we can proceed by writing equation (6). All the variables in equation (6) are $I(0)$ and thus, the equation describes the short-run relationship between $y_t$ and $x_t$. Equation (4) is considered to describe the long-run relationship between the variables.

Engle and Granger suggested estimating equation (4) to determine the value of $\theta$ and then replacing this estimated value of $\theta$ into equation (6) to determine the values of $\alpha$ and $\lambda$. The values of $\alpha$ and $\lambda$ will describe the short-run characteristics and $\theta$ will describe the long-run relationship.

**General Multivariate Case**

Consider the following multivariate equation

$$X_t = A_1X_{t-1} + A_2X_{t-2} + A_3X_{t-3} + \ldots + A_pX_{t-p} + \epsilon_t$$  \hspace{1cm} (7)

where $X_t$ is an (nx1) vector composed of $Z_t - \mu$, where $Z_t$ is a vector of economic time series variables and $\mu$ is the vector of the means of $Z$ and $A_1$, $A_2$, ..., $A_p$ are (nxn) matrices.

Reparameterizing the above equation, we can write

$$\Delta X_t = \Gamma_1\Delta X_{t-1} + \Gamma_2\Delta X_{t-2} + \ldots + \Gamma_{p-1}\Delta X_{t-k+1} + \Pi X_{t-1} + \epsilon_t.$$  \hspace{1cm} (8)

The matrix $\Pi = (I - A_1 - A_2 - \ldots - A_p)$. 
The rank of $\lambda$ is the number of linearly independent and stationary linear combinations of $X_t$ that can be found. That is, it is the number of linearly independent cointegrating relations among the variables in $X_t$. The objective of testing for cointegration is to test for the rank of $\Pi$ by testing whether the eigenvalues of the estimated $\Pi$ matrix are significantly different from zero or not.

If the $\Pi$ matrix is full rank, then any linear combination of $X_t$ will be stationary. If $\Pi$ is a matrix of zeros, then any linear combination of $X_t$ will be a unit root process and thus nonstationary. Finally, the third case is where $\Pi$ is not a matrix of zeros but is also less than full rank.

If there are several variables which are cointegrated, then we have cointegrating vectors. Cointegrating vectors are obtained from the reduced equations where all the variables are assumed to be jointly endogenous. The cointegrating vectors may be considered as rising from a constraint that an economic structure imposes on the long-run relationship among the jointly endogenous variables.

**Johansen's Approach to Integration**

Johansen's approach to integration is slightly more complicated. Consider the following multivariate model which was considered earlier:

$$X_t = A_1X_{t-1} + A_2X_{t-2} + A_3X_{t-3} + \ldots + A_pX_{t-p} + \epsilon_t$$  

(7)
where \( X_t \) is an \((nx1)\) vector composed of \( Z_t - \mu \), where \( Z_t \) is a vector of economic time series variables and \( \mu \) is the vector of the means of \( Z \) and \( A_1, A_2, \ldots, A_p \) are \((nxn)\) matrices.

Reparameterizing the above equation we can write:

\[
\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \ldots + \Gamma_{p-1} \Delta X_{t-k+1} + \Pi X_{t-1} + \epsilon_t. \tag{8}
\]

The optimal lag of the model may be determined by Akaike's final prediction error criterion. Now consider the fact that any \((nxn)\) matrix, \( \Pi \), of rank \( k<n \) can be written as the product of two \((nxk)\) matrices of rank \( k \). That is, \( \Pi \) is made up of \( \alpha \beta' \), where \( \alpha \) and \( \beta \) are \((nxk)\) matrices of rank \( k \).

In this case the \( \Pi \) matrix contains the information about the long-run relationships between the \( X_t \) series. \( \alpha \) is composed of coefficients that represent the speed of adjustment and \( \beta \) is made up of \( k \) cointegrating vectors that satisfy \( e_t = \beta' X_t \), where \( e_t \) is integrated of order zero and \( X_t \) is the vector of time series.

Maximizing the likelihood function for \( X_t \) conditional on any given \( \beta \) using standard least squares formula for regression of \( \Delta X_t \) on \( \Delta X_{t-1}, \Delta X_{t-2}, \ldots, \Delta X_{t-p+1} \) and \( \epsilon_t' X_{t-p} \) gives the estimates of \( \Gamma_1, \Gamma_2, \ldots, \Gamma_{p-1} \) and \( \alpha \) conditional on \( \beta \). After this is done, the row space of \( \beta \) may be determined.

The rank of \( \Pi \) may be determined by computing canonical correlations between \( \Delta X_t \) and \( X_{t-p} \), adjusting for all intervening lags. Johansen chooses to put the lag level at the largest. \(-\alpha \beta'\) is the coefficient matrix on the lagged level. Upon premultiplying equation (7) above with \( \beta' \), the
last term becomes $\beta' \alpha \beta' X_{t-p}$. $\beta' \alpha$ has no zero eigenvalues so that $\beta' X_t$ is a stationary vector time series of dimension $k$. Thus, the rows of $\beta'$ are the cointegrating vectors.

Once we have determined the number of cointegrating vectors, the next question is, are these cointegrating vectors unique. To determine the uniqueness of the vector(s) we will be interested in determining the rank of the $\Pi$ matrix. We are particularly interested in testing the hypothesis that $H_0: r = 1$. If it is found that $r = 1$, then $\beta$, obtained from solving a standard eigenvalue problem, is unique and the appropriate relationship between exchange rates, prices and monetary base can be identified. However, if $r = m$, then the fact that $X_t$ is stationary cannot be rejected. If $0 < r < m$, then there is evidence in favor of cointegration among the series $X_t$.

Because of the difficult nature of the Johansen approach, the following is a step-by-step outline of the Johansen approach. Consider the following multivariate model:

$$X_t = A_1 X_{t-1} + A_2 X_{t-2} + A_3 X_{t-3} + \ldots + A_p X_{t-p} + \epsilon_t.$$  \hspace{1cm} (9)

Step 1 - Pick an autoregressive order $p$ for the model. The determination of this order may be done in several ways. Using Akaike's final prediction error criterion is one of these methods.
Step 2 - Run a regression of $\Delta X_t, \Delta X_{t-1}, \Delta X_{t-2}, \ldots, \Delta X_{t-p+1}$ and output the residuals, $D_t$. For each $t$, $D_t$ has $n$ elements.

Step 3 - Regress $X_{t-p}$ on $\Delta X_{t-1}, \Delta X_{t-2}, \ldots, \Delta X_{t-p+1}$ and output the residuals, $L_t$. For each $t$, $L_t$ has $n$ elements.

Step 4 - Compute the squares of the canonical correlations between $D_t$ and $L_t$, calling these $\delta_1^2 > \delta_2^2 > \ldots \delta_n^2$. These squared canonical correlations are the solution to the determinantal equation

$$\det(S_{kk} - (S_{k0} S_{00}^{-1} S_{0k}')) = 0$$

where

$$S_{kk} = N^{-1} \sum_{t=1}^n L_t L_t' S_{00} = N^{-1} \sum_{t=1}^n D_t D_t'$$
$$S_{k0} = N^{-1} \sum_{t=1}^n L_t D_t'$$

$D_t$ and $L_t$ are column vectors of residuals from steps 2 and 3.

Step 5 - At this point there is a possibility of choosing one of two directions or both.

a) Letting $N$ denote the number of time periods available in the data, compute the trace test as

$$\text{TRACE TEST} = -N \sum_{i=k+1}^n \ln(1-\delta_i^2).$$

The null hypothesis is "there are $k$ or less cointegrating vectors."
b) The other option is use the maximal eigenvalue test, which uses the \( k+1^{th} \) largest squared canonical correlation or eigenvalue, as follows:

\[
\text{MAX EIGENVALUE TEST} = -N \ln(1 - \delta_{k+1}^2).
\]

**Step 6** - Compare the test to the appropriate table in Johansen and Juselius (1990). Determining the appropriate table depends on the role of the intercept term in the model. A discussion on this may be found in Dickey and Rossana (1990).

Johansen's approach to integration is employed in this study, as opposed to the Engle-Granger two-step approach, because of the distributional considerations. The Engle-Granger approach can give insight into the cointegrating nature of the data matrix. However, the problem is that it does not account for the possible existence of multiple cointegrating vectors among variables and does not have a well defined limiting distribution. Monte Carlo studies have indicated that although cointegrating regressions have excellent large sample properties, they have significant small-sample bias and this is why they have an ill defined distribution function.
CHAPTER VI
EMPIRICAL ANALYSIS

In attempting to empirically verify Driskill's results, I chose the German mark and the U.S. dollar as the comparison currencies. As was mentioned earlier, the vector, $X_t$, comprises the exchange rate, $e_t$, the relative price level, $p_t$, the relative money supply, $m_t$, and the relative measurement of income, $y_t$. The consumer price index is used as an indicator of the price level. Base money is used as an indicator of the money supply and the Gross National Product is used as an indicator of income. The data are delineated by quarters from 1973.1 to 1990.4.

It should be mentioned that several objections concerning the data set may be raised. The German economy is an open economy where prices reflect import and export activity. However, the U.S. is comparatively less open and thus the use of the CPI may not accurately reflect the price level of traded products. Wholesale or industrial prices may be a better measure of prices, but the open economy/less open economy representation problem may remain. Also, another point to consider is that Taylor (1988) rejected cointegration for the German mark and relative to the U.S. dollar (as well as a number of others) for the 1970s floating exchange rate period.
Reestimation of Driskill's Analysis

Since the data set used here is quite different from the one used by Driskill, an attempt was made to estimate his model using mark/dollar exchange rates using his final reduced form equation for comparison. Era or seasonal dummy variables are not used in this estimation. The results of the OLS regression are shown below. The t-ratios are shown in parentheses.

\[
e_t = 0.10306 + 0.98878e_{t-1} - 0.20385m_t + 0.19889m_{t-1} \\
(-0.7868) (25.136) (-1.447) (1.4596) \\
- 0.13620p_{t-1} - 0.86003y_t + 1.0113y_{t-1} \\
(-0.8940) (-1.6579) (2.0982)
\]

\[R^2 = 0.93323 \quad R^2(\text{adj}) = 0.92697\]

Excluding the income variable, the following OLS results are obtained.

\[
e_t = 0.02340 + 0.97873e_{t-1} - 0.16029m_t + 0.24753m_{t-1} \\
(0.6692) (25.782) (-1.247) (1.9280) \\
- 0.03685p_{t-1} \\
(-0.5680)
\]

\[R^2 = 0.92878 \quad R^2(\text{adj}) = 0.92341\]

Clearly, the data presented here is inconclusive. It is not entirely consistent with either the Dornbusch or stock/flow models. The sign and significance of the first coefficient would indicate a partial consistency with the stock/flow model. A test that the summation of exchange rate lag, relative monetary base and relative price variables equal to one was made and indicates the hypothesis of PPP holding in the long run cannot be rejected.
Estimation of the Long-Run Relationships: The Johansen Approach

Before attempting to estimate the long-run relationships, it is important to keep in mind that one of the criticisms of using the German/U.S. data set is that these two countries are not entirely compatible since there are more trade restrictions placed in one than in the other. For this reason it is not entirely clear what the coefficients of the ratios of these two countries would mean. Thus, it would make more sense to analyze the data in the absolute form and not in the ratio form.

The first step is to perform Dickey-Fuller tests to determine the order of integration. The Dickey-Fuller tests for the following variables (in logarithmic form) — the exchange rate (LER), the German monetary base (LGBASE), the U.S. monetary base (LUSBASE), the adjusted German consumer price index (LGACPI), the adjusted U.S. consumer price index (LUSACPI), the German GNP (LGGNP), and finally the U.S. GNP (LUSGNP)—indicate that the data matrix is integrated of order one.

Next, using the above data matrix, the results of the tests for the rank of Π (maximal eigenvalue and Johansen's Trace test) are shown below (tables 1 and 2).
### TABLE 1

**Johansen Maximum Likelihood Procedure**  
(Trended case, with trend in DGP)  
Cointegration LR Test Based on Maximal Eigenvalue  
of the Stochastic Matrix

<table>
<thead>
<tr>
<th>Null</th>
<th>Alternative</th>
<th>Statistic</th>
<th>Critical Value 95%</th>
<th>Critical Value 90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r = 0$</td>
<td>$r = 1$</td>
<td>54.9212</td>
<td>45.2770</td>
<td>42.3170</td>
</tr>
<tr>
<td>$r &lt;= 1$</td>
<td>$r = 2$</td>
<td>50.0024</td>
<td>39.3720</td>
<td>36.7620</td>
</tr>
<tr>
<td>$r &lt;= 2$</td>
<td>$r = 3$</td>
<td>39.1598</td>
<td>33.4610</td>
<td>30.9000</td>
</tr>
<tr>
<td>$r &lt;= 3$</td>
<td>$r = 4$</td>
<td>18.0014</td>
<td>27.0670</td>
<td>24.7340</td>
</tr>
<tr>
<td>$r &lt;= 4$</td>
<td>$r = 5$</td>
<td>9.3357</td>
<td>20.9670</td>
<td>18.5980</td>
</tr>
<tr>
<td>$r &lt;= 5$</td>
<td>$r = 6$</td>
<td>4.3144</td>
<td>14.0690</td>
<td>12.0710</td>
</tr>
<tr>
<td>$r &lt;= 6$</td>
<td>$r = 7$</td>
<td>.1288</td>
<td>3.7620</td>
<td>2.6870</td>
</tr>
</tbody>
</table>

### TABLE 2

**Johansen Maximum Likelihood Procedure**  
(Trended case, with trend in DGP)  
Cointegration LR Test Based on Trace  
of the Stochastic Matrix

<table>
<thead>
<tr>
<th>Null</th>
<th>Alternative</th>
<th>Statistic</th>
<th>Critical Value 95%</th>
<th>Critical Value 90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r = 0$</td>
<td>$r = 1$</td>
<td>175.8637</td>
<td>124.2430</td>
<td>118.5000</td>
</tr>
<tr>
<td>$r &lt;= 1$</td>
<td>$r = 2$</td>
<td>120.9425</td>
<td>94.1550</td>
<td>89.4830</td>
</tr>
<tr>
<td>$r &lt;= 2$</td>
<td>$r = 3$</td>
<td>70.9401</td>
<td>68.5240</td>
<td>64.8430</td>
</tr>
<tr>
<td>$r &lt;= 3$</td>
<td>$r = 4$</td>
<td>31.7803</td>
<td>47.2100</td>
<td>43.9490</td>
</tr>
<tr>
<td>$r &lt;= 4$</td>
<td>$r = 5$</td>
<td>13.7789</td>
<td>29.6800</td>
<td>26.7850</td>
</tr>
<tr>
<td>$r &lt;= 5$</td>
<td>$r = 6$</td>
<td>4.4432</td>
<td>15.4100</td>
<td>13.3250</td>
</tr>
<tr>
<td>$r &lt;= 6$</td>
<td>$r = 7$</td>
<td>.1288</td>
<td>3.7620</td>
<td>2.6870</td>
</tr>
</tbody>
</table>
The order of the lag in the vector autoregression (VAR) was determined by optimizing on the final prediction error, and the order of lag is 2 (or two quarters). The maximal eigenvalue and trace of the stochastic matrix, shown in tables 1 and 2, indicate that the number of cointegrating vectors is 3. The rank of \( \Pi \) is less than \( m = 7 \), suggesting \( X_t \) is not stationary but that the series contained in \( X_t \) are cointegrated. It is particularly important that exchange rates and prices are cointegrated.

The constant term in a vector autoregression system (VAR) with a unit root captures the possible existence of a deterministic trend. Since \( \Delta X_t \) is a stationary time series, it can be written as:

\[
C(L)(\epsilon_t + \mu) = C(L)\epsilon_t + C(L)\mu
\]

where \( C(L) \) is a matrix of constants and the \( L \) is a lag operator, and \( \mu \) is likewise a vector of constants. There may also be a set of centered seasonal dummy variables that are included in the model in order to obtain \( \epsilon_t \) as white noise, but we do not include such in this explanation. Assuming \( \epsilon_t = 0 \) for all \( t \leq 0 \), and conditional on the initial values \( X_0 \), we can solve recursively for and \( X_t \) to obtain:

\[
X_t = X_0 + \Sigma_i^t \Sigma_j^{t-i} C_j\epsilon_i + C(1)\mu t.
\]

It follows that \( X_t \) is nonstationary with linear deterministic trend \( C(1)\mu t \). Johansen (1988) proves that if \( \Pi = \alpha\beta' \) and the rank \( (\alpha_i'\Pi_1(1)\beta_i) = m - r \), then the matrix \( C(1) \)
\[ = \beta_1(\alpha_1' \Pi_1(L) \beta_1) \alpha_1', \]
where \( \Pi(L) = \Pi(1) + \Pi_1(L)(1 - L), \) \( \alpha_1 \) and \( \beta_1 \) are \((m \times (m-r))\) matrices such that \( \alpha_1' \alpha = 0 \) and \( \beta_1' \beta = 0 \).

Therefore, the restriction \( \alpha' \mu = 0 \) implies that the nonstationary process \( X_t \) does not have a deterministic linear trend, i.e., \( C(1) \mu = 0, \) and \( \mu \) belongs to the null space of \( C(1). \) This hypothesis can be expressed as \( \mu = \alpha \beta_0', \)
where \( \beta_0 \) is a vector of \((r \times 1)\) dimension that captures nonzero means in the long-run relationships. This means that \( \mu \) belongs to the cointegrating space. So the model with no time trend can be written as:

\[
\Delta X_t = \alpha B' X_{t-1} + \alpha B_0' + \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \epsilon_t. \tag{5}
\]

The test of the absence of a deterministic trend in the VAR is by the use of a likelihood ratio test statistic for the null hypothesis \( \Pi = \alpha \beta', \mu = \alpha \beta_0' \) against the alternative hypothesis, \( \Pi = \alpha \beta'. \) The likelihood ratio is given by:

\[-T \sum \ln \left(1 - \lambda_i^0 \right)/ \left(1 - \lambda_i \right), \]
where \( \lambda_i^0 \) and \( \lambda_i \) are the eigenvalues under the null and alternative hypotheses, respectively.

The statistic is asymptotically distributed as \( \chi^2 \) with \((m-r-1)\) degrees of freedom. The VAR was estimated with and without trend to obtain the eigenvalues and the calculated \( \chi^2 = 27.56 \) with 3 degrees of freedom, which is significant at \( p = 0.01 \) level and suggests rejection of the hypothesis of no trend.

The estimated cointegrating vectors giving the cointegrating coefficients, \( \beta, \) for the number of vectors, \( r = 3, \) are provided in table 3 below. The adjustment
coefficients, $\alpha$, are given in table 4.

### TABLE 3

Estimated Cointegrated Vectors, $\beta$, with Maximum Lag of the VAR Equal to 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Vector 1</th>
<th>Vector 2</th>
<th>Vector 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>LER</td>
<td>0.988</td>
<td>-0.248</td>
<td>1.199</td>
</tr>
<tr>
<td>LGBASE</td>
<td>0.879</td>
<td>-0.627</td>
<td>-4.080</td>
</tr>
<tr>
<td>LUSBASE</td>
<td>4.009</td>
<td>-5.614</td>
<td>2.582</td>
</tr>
<tr>
<td>LGCAPI</td>
<td>-6.350</td>
<td>-2.271</td>
<td>-9.462</td>
</tr>
<tr>
<td>LUSACPI</td>
<td>4.640</td>
<td>-2.419</td>
<td>3.087</td>
</tr>
<tr>
<td>LGGNP</td>
<td>1.183</td>
<td>7.931</td>
<td>10.079</td>
</tr>
<tr>
<td>LUSGNP</td>
<td>-5.713</td>
<td>2.291</td>
<td>-4.471</td>
</tr>
</tbody>
</table>

### TABLE 4

Estimated Adjustment Matrix, $\alpha$, with Maximum Lag of the VAR Equal to 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Vector 1</th>
<th>Vector 2</th>
<th>Vector 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>LER</td>
<td>-0.006</td>
<td>-0.051</td>
<td>-0.086</td>
</tr>
<tr>
<td>LGBASE</td>
<td>-0.026</td>
<td>0.189</td>
<td>0.173</td>
</tr>
<tr>
<td>LUSBASE</td>
<td>-0.025</td>
<td>0.118</td>
<td>-0.031</td>
</tr>
<tr>
<td>LGACPI</td>
<td>0.025</td>
<td>0.009</td>
<td>-0.004</td>
</tr>
<tr>
<td>LUSACPI</td>
<td>-0.014</td>
<td>0.045</td>
<td>0.008</td>
</tr>
<tr>
<td>LGGNP</td>
<td>-0.004</td>
<td>0.005</td>
<td>-0.019</td>
</tr>
<tr>
<td>LUSGNP</td>
<td>0.030</td>
<td>0.0006</td>
<td>-0.006</td>
</tr>
</tbody>
</table>

The individual elements of $\alpha$, $\alpha_{ij}$, measure the speed with which the $i$th variable of the system reacts to deviations from the $j$th long-run relationship.
The long-run matrix, $\Pi = \alpha \beta'$, as estimated, is given in table 5. The coefficients shown are the error correction coefficients (coefficients of the equilibrium error). Graphs of the three cointegrating residuals are shown in figures 9 - 11 below, and indicate a form of stationarity, particularly using the third vector of $\beta$ (figure 11).

If we focus interest only on the exchange rate, then the coefficient of the exchange rate has the expected negative sign (see table 5). There is indication that 9.6 percent (the left most top coefficient in the table) of a deviation of the exchange rate from its long-run pattern (purchasing power parity) is reversed each quarter from the

![Residuals](image)

**Fig. 9** -- Residuals of cointegrating vector 1
Fig. 10 -- Residuals of cointegrating vector 2

Fig. 11 -- Residuals of cointegrating vector 3
TABLE 5

Estimated Long-Run Matrix, $\Pi = a\beta'$

<table>
<thead>
<tr>
<th></th>
<th>LER</th>
<th>LGBASE</th>
<th>LUSBASE</th>
<th>LGACPI</th>
<th>LUSACPI</th>
<th>LGGNP</th>
<th>USGNP</th>
</tr>
</thead>
<tbody>
<tr>
<td>LER</td>
<td>-0.096</td>
<td>0.379</td>
<td>0.044</td>
<td>0.969</td>
<td>-0.168</td>
<td>-1.285</td>
<td>0.300</td>
</tr>
<tr>
<td>LGBASE</td>
<td>0.134</td>
<td>-0.846</td>
<td>-0.723</td>
<td>-1.895</td>
<td>-0.048</td>
<td>3.210</td>
<td>-0.186</td>
</tr>
<tr>
<td>LUSBASE</td>
<td>-0.091</td>
<td>0.039</td>
<td>-0.842</td>
<td>0.183</td>
<td>-0.496</td>
<td>0.594</td>
<td>0.551</td>
</tr>
<tr>
<td>LGACPI</td>
<td>0.018</td>
<td>0.039</td>
<td>0.082</td>
<td>-0.117</td>
<td>0.099</td>
<td>-0.008</td>
<td>0.119</td>
</tr>
<tr>
<td>LUSACPI</td>
<td>-0.015</td>
<td>-0.0073</td>
<td>-0.287</td>
<td>-0.090</td>
<td>-0.148</td>
<td>0.421</td>
<td>0.146</td>
</tr>
<tr>
<td>LGGNP</td>
<td>-0.028</td>
<td>0.070</td>
<td>-0.094</td>
<td>0.194</td>
<td>-0.090</td>
<td>-0.155</td>
<td>0.120</td>
</tr>
<tr>
<td>USGNP</td>
<td>0.022</td>
<td>0.053</td>
<td>0.104</td>
<td>-0.131</td>
<td>0.120</td>
<td>-0.028</td>
<td>-0.144</td>
</tr>
</tbody>
</table>

response of the exchange rate alone. The domestic price effect on exchange rate is of the expected sign as well. The U.S. price effect is negative and there are mixed effects of domestic and foreign monetary base on exchange rate.

Testing Restriction on the Cointegrating Vectors

The matrix, $\beta$, given in table 3 cannot be uniquely identified since evidence from both Johansen's maximum eigenvalue and trace tests (tables 1 and 2, respectively) indicates that there is more than one (and up to three) cointegrating vector. The vectors given span the column space of $\beta$, i.e., they span the cointegrating space. When there is only one cointegrating vector, that linear combination of the variables involved is the unique stationary combination. In the Germany/U.S. case there are three vectors, so there are at least three long-run
relationships that are observationally equivalent to those which have generated the data. We could consider $\Pi = \alpha \beta'$ as a system of equations. When $r > 1$, the values of $\alpha$ and $\beta$ cannot be uniquely recovered from an estimate of $\Pi$. Therefore, estimation of $\Pi = \alpha \beta'$ using OLS procedures does not capture this possible nonuniqueness. This leads to a test on the cointegrated vectors. That is a test for known and/or trivial cointegrating vectors needs to be performed.

The likelihood ratio test of Johansen-Juselius (1990) is used to test for known, but specifically trivial, vectors, since we have three vectors. These tests are performed by placing restrictions on the cointegrating vectors, $\beta$. Johansen's definition of cointegration allows for some of the individual variables to be stationary. It only requires the vector time series $X_t$ to be nonstationary as a vector process. Trivial cointegrating vectors may exist since one can always form a linear combination of a stationary variable and a nonstationary one that assigns a unit coefficient to the former and a zero coefficient to the latter. If only trivial cointegrating vectors exist, the argument that exchange rate and other variables are linked by long-run relationships is destroyed.

A unit coefficient was assigned alternatively to the $i$th variable and zero coefficients to the remaining variables as alternative restrictions on $\beta$. A likelihood ratio test statistic was then calculated for each
restriction having an asymptotic $\chi^2$ distribution (Johansen and Juselius 1990) with $(m-r)r_1$ degrees of freedom, for $r_1$ known vectors and $r = r_1 + r_2$ total vectors. Again the statistic is a function of three eigenvalues, i.e., the $r$ largest eigenvalues solved for in steps 4 and 5 of the Johansen MLE procedure discussed earlier or the $(m - r_1)$ greatest eigenvalues solved from determining the $r_1$ known vectors, and the $r_2$ largest eigenvalues associated with the problem of deriving $r_2$ unknown vectors.

The likelihood ratio test statistics for the coefficients for each variable of the Germany/U.S. VAR system are given in table 6. The statistics for each variable are significantly different from the critical values indicating rejection of the hypothesis of trivial cointegrating vectors in the Germany/U.S. case. This is an indication that there is a possible link between the exchange rate and the other economic forces which have been included in the model in a long-run relationship.

Another important investigation is to determine if the domestic and foreign fundamentals that are operating are reflective of the basic monetary model of exchange rate behavior which underlies the basic modeling of this study. Tests between pairs of domestic and foreign fundamentals are
developed using the form: \( H_i: \beta = (b_i, \psi) \), where \( b_i = (0,1,-1,0,0,0,0) \) and \( \psi \) being a \((m \times (r-1))\) matrix of cointegrating vectors, and for \( i=1 \) as given for \( b_i \) being the hypothesis that the logarithm of the domestic to foreign monetary base ratio is stationary by itself. Similarly, for \( i=2 \), the hypothesis is that logarithm of the price domestic to foreign price ratio is stationary, and for \( i=3 \), the hypothesis is that the logarithm of the domestic to foreign income ratio is stationary by itself, giving us, respectively, \( b_2 = (0,0,0,1,-1,0,0) \) and \( b_3 = (0,0,0,0,1,-1) \). If these hypotheses are accepted, there is evidence of long-run relationships that keep domestic and foreign fundamentals at a constant difference so deviations from that level are only temporary. Again, likelihood ratio statistics are calculated for these three restriction cases the same way as was done to test for trivial cointegrating vectors, except for the \( 1,-1 \) restrictions on the domestic/foreign fundamentals. These ratios are given in table 7.
TABLE 7  
Likelihood Ratio Statistics for Tests of Cointegration  
Between Monetary Model Fundamentals  

<table>
<thead>
<tr>
<th></th>
<th>LGBASE - LUSBASE</th>
<th>LGACPI - LUSACPI</th>
<th>LGGNP - LUSGNP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.992</td>
<td>27.921</td>
<td>20.678</td>
</tr>
</tbody>
</table>

° Significantly different from the critical value at 1% N level

Only the monetary base differential in the Germany/U.S. system is found to be stationary, i.e., we fail to reject the hypothesis of stationarity between domestic and foreign monetary base at the 1 percent level. So long-run relationships between the price levels as well as income levels apparently do not exist. That is, there are apparently no long-run relationships that keep domestic and foreign fundamentals for prices and income at constant differences and setting up deviations from long-run equilibrium as temporary deviations.

Given this result there is some question of the validity of the monetary model for understanding exchange rate behavior in the Germany/U.S. case. Therefore, some further tests of restrictions on all cointegrating relationships were carried out. These restrictions are in the matrix form of $\beta = J\psi$, where $J$ is a $(m \times s)$ matrix of constants and $\psi$ is a $(s \times r)$ matrix of unknown coefficients. If $\beta'X_t$ is a stationary $r$-dimensional process, then these restrictions imply that $\psi'J'X_t = \psi'\beta'X_t$ is a stationary $s$-
dimensional vector or \( s \) being the dimension of the restrictions. Thus, the cointegration space lies in the subspace spanned by the columns of \( \psi \). The formal test of this type of hypothesis is carried out by estimating the restricted cointegration space and deriving the \( r \) eigenvectors associated with the \( r \) largest eigenvalues of the characteristic equation, \( |\lambda J' s_{11} J - J' s_{10} s^{-1} s_{01} J| = 0 \). The likelihood ratio test of the null hypothesis of \( \beta = J \psi \) against the alternative \( \beta = a \beta' \) is given by \( \sum \ln \left( \frac{1-\lambda_{0i}}{1-\lambda_{1i}} \right) \) for \( \lambda_{0i} \) and \( \lambda_{1i} \) being, respectively, the eigenvalues under the null and the alternative hypotheses. Again the statistics are distributed as \( \chi^2 \) with \( r(m-s) \) degrees of freedom. The important test of this nature that needs to be made is a test for the exclusion of any one variable (monetary model fundamental influence on exchange rate behavior) from all the cointegrating vectors. With any one of the variables defined in the model excluded from all long-run relationships, the long-run behavior of the system does not depend on that particular variable. This does not, however, imply that the dynamics of that variable are not affected by the deviations from the long-run relationships. This latter situation is another phenomenon that needs consideration in a subsequent test to be completed.

In testing for the absence of the \( i \)th variable from all cointegrating vectors, the matrix \( J \) takes the form of a \((7 \times 7)\) identity matrix with the \( i \)th column deleted, such as
if the test is on exclusion of the exchange rate itself as given by,

\[
\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0
\end{pmatrix}
\]

\( J = 001000 \)
\( 000100 \)
\( 000010 \)
\( 000001 \)

The likelihood ratio statistics are given in table 8 for each of the variables defined for the underlying model.

**TABLE 8**

<table>
<thead>
<tr>
<th>LER</th>
<th>LGBASE</th>
<th>LUSBASE</th>
<th>LGACPI</th>
<th>LUSACPI</th>
<th>LGGNP</th>
<th>LUSGNP</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.56</td>
<td>22.04</td>
<td>31.50</td>
<td>17.10</td>
<td>28.37</td>
<td>24.29</td>
<td>30.46</td>
</tr>
</tbody>
</table>

* All ratios are significantly different at the 1% level

None of the variables defined for the Germany/U.S. system can be excluded from all cointegrating vectors since all ratios given in Table 8 are significantly different from the tabular critical values at the 1 percent level.

We still need to know if the nontrivial cointegrating vectors that have been found reflect the restrictions given by the underlying monetary equation that the logarithm of the exchange rate is related to the logarithmic differentials of the monetary base, the price and the incomes of Germany and the U.S. In the VAR given by the vector
\( X_t = [\text{LER}, \text{LBASE}, \text{LUSBASE}, \text{LGACPI}, \text{LUSCPI}, \text{LGGNP}, \text{LUSGNP}] \) defined in this study, a test of the equality of the coefficients in absolute terms was made, first of those coefficients associated with the domestic and foreign monetary base, then prices, and finally incomes. The test statistic derived is again the likelihood ratio statistic formed from the likelihood of the null hypothesis \( \beta = (G, J_1 \psi) \) for \( G \) a \((7 \times 2)\) matrix of trivial cointegrating vectors (and we have previously determined there are no trivial vectors), and for \( J_i \) is any of the \((7 \times 6)\) matrices \( J_1, \ldots, J_3 \) defined as for example testing for equality of the coefficients on the monetary base by,

\[
J_1 = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 1 \\
1 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
\]

and continuing for the other vectors, with 1, -1 in the fourth row-fourth column and fifth row-fourth column elements, respectively, for \( J_2 \), and again in the sixth row-sixth column and seventh row-sixth column elements, respectively, for \( J_3 \). One is actually testing for the equality of \( \beta_{12} = -\beta_{13} \) for the coefficients of the domestic and foreign monetary base, respectively, and \( \beta_{14} = -\beta_{15}, \beta_{16} = -\beta_{17} \) in this case for, respectively, the prices and the incomes. \( \psi \) is the unknown \((6 \times r_2)\) matrix, where \( r_2 = r - 2 \). The alternative hypothesis is \( \beta = (G, \psi) \). Here, in order to
get the likelihood ratio statistic, one solves for the largest eigenvalues associated with two different eigenvalue problems, one being the problem to find eigenvalues for testing for known cointegrating vectors (which was used earlier to test for trivial cointegrating vectors), and the other solving for the eigenvalues from the problem associated with testing for linear restrictions on all cointegrating relationships (which was carried out to test for exclusion of variables above). The likelihood ratio statistic is just $T$ (the number of observations) multiplied by the ratio of the summation over all vectors of the logarithm of one minus each eigenvector of each respective eigenvalue problem. $r_2$ is the degrees of freedom used. Table 9 contains the likelihood ratio statistics.

**TABLE 9**

<table>
<thead>
<tr>
<th>LGBASE - LUSBASE</th>
<th>LGCAPI - LUSACPI</th>
<th>LGGNP - LUSGNP</th>
</tr>
</thead>
<tbody>
<tr>
<td>32.974</td>
<td>15.847</td>
<td>28.639</td>
</tr>
</tbody>
</table>

*All ratios are significant at the 1% level*

None of the hypotheses is accepted for the Germany/U.S. system. It also needs to be made clear that usual practice of restricting the coefficient of, in our case, (LGBASE - LUSBASE), to be equal to one, has not been followed in the
restrictions which have just been explained.

From the application of the above restricted estimation and test procedures, we have found three cointegrating vectors in the Germany/U.S. case which link exchange rate behavior with macroeconomic fundamentals. None of these are trivial, suggesting there are equations of long-run exchange rate determination. None of the macroeconomic fundamental forces influencing exchange rate behavior as defined in this study can be excluded from all cointegrating vectors. However, the cointegrating vectors do not appear to satisfy the restrictions imposed by the original monetary model of exchange rate determination, even though they do represent long-run relationships of mark-to-dollar reactions to permanent changes in the macroeconomic fundamentals.

Tests on the Coefficients of the Adjustment Matrix

We have concentrated to this point on the cointegrating vectors with very little mention of the loadings or adjustment matrix, $\alpha$. This latter matrix measures the weights with which the error correction term enters each equation of the error correction model. The individual elements of this matrix measure how the exchange rate reacts in the short run to transitory deviations of the fundamentals from their long-run values. They capture the short-run dynamics of the exchange rate.
The short-run dynamics of the exchange rate and all the other variables in the system are determined by the error correction model, here reproduced as:

$$\Delta x_t = \alpha \beta' x_{t-1} + \Gamma_1 \Delta x_{t-1} + \ldots + \Gamma_{k-1} \Delta x_{t-k+1} + \mu + \epsilon_t. \quad (6)$$

This VARECM (vector autoregression-error correction model) indicates how the variables change over time as a function of a) the deviations of the r long-run equilibrium relationships; b) past changes in all variables; c) a purely deterministic component (constant term as given, but could include seasonal components); and d) a stochastic disturbance. It is the first component and first term as given in the VARECM on which we now concentrate given our findings on the cointegrating vectors, particularly $\alpha$. This matrix indicates how the variables included in the model react to the stationary equilibrium errors $\beta' x_t = z_t$. With this definition, the error correction model can be expressed as:

$$\Delta x_t = \alpha z_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta x_{t-i} + \mu + \epsilon_t. \quad (7)$$

An element of $\alpha$, say $\alpha_{ij}$, measures the speed with which the ith variable of the vector system reacts to deviations from the jth long-run relationship. If $\alpha_{ij} = 0$ for $j = 1, \ldots, r$, then the ith variable can be considered as weakly exogenous with respect to the parameters of interest $\beta$. Then the estimation of $\beta$ could be performed conditional on the ith variable and by reducing the dimensionality of the system and estimation.
The test for weak exogeneity is a test of $\alpha_{ij} = 0$ for $j = 1, \ldots, r$ against the alternative $I = \alpha \beta'$. This amounts to testing the model

$$\Delta x_{it} = \gamma_{it} \Delta x_{t-1} + \ldots + \gamma_{k-1} \Delta x_{t-k+1} + \mu_i + \epsilon_{it}, \quad (8)$$

relative to the model of (12) for the weak exogeneity of the $i$th variable. With the test on exchange rate itself, then $i = 1$, and the $\gamma$ parameters are the first rows of the $\Gamma$, and similarly for $\mu$, $\Delta x_t$, and $\epsilon_t$. So stationary deviations from the long-run relationships do not affect the short-run dynamics of the weakly exogenous variables through the error correction term. The likelihood ratio test statistic (Johansen 1988) is then formed as the summation of the ratios of the logarithms of one minus the eigenvalues found by solving the roots of the characteristic equation associated with the model restricted for $\alpha_{ij} = 0$ and one minus the eigenvalues associated with solving the eigenvector problem for $I = \alpha \beta'$ as was done for the original VARECM system. This ratio is again multiplied by the number of observations in the sample. These likelihood ratio statistics are presented for the test of weak exogeneity of every variable defined in the system of this study in table 10. The degrees of freedom for this test are $r(m-s)$, where $s$ is the number of remaining variable coefficients not restricted in $\alpha$. 
TABLE 10
Likelihood Ratio Test Statistics for Tests of Weak Exogeneity of Each Variable

<table>
<thead>
<tr>
<th></th>
<th>LER</th>
<th>LGBASE</th>
<th>LUSBASE</th>
<th>LGACPI</th>
<th>LUSACPI</th>
<th>LGGNP</th>
<th>LUSGNP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.031*</td>
<td>7.981b</td>
<td>11.852c</td>
<td>22.389f</td>
<td>14.321c</td>
<td>10.386d</td>
<td>6.413*</td>
</tr>
</tbody>
</table>

* Not significant at the 10% level  
b Significant at the 5% level  
c Significant at the 1% level  
d Significant at the 2.5% level

We cannot reject the hypothesis of weak exogeneity of both the exchange rate and U.S. income at least using the p = 0.10 value. What this means is that the short-run dynamics of the exchange rate are not affected by transitory deviations from the long-run equilibrium relationships. One other interesting implication of this evidence is that the error correction model that has here been fitted to the Germany/U.S. data is not compatible with the asset market view of exchange rate determination (Mussa 1983; Finn 1986; and Meese and Singleton 1982). The asset market view suggests that the exchange rate in period t is related linearly to combination of macroeconomic fundamentals and to the expected difference between the exchange rate in a future (t+1) period and the current period. This particular model meets not only monetary models but many others as well.
Summary

The objectives of this study were to first provide an historical perspective on exchange rate behavior and policy that have influenced exchange rates since the gold-standard era, then to outline the theory of exchange rate behavior as related to macroeconomic fundamentals, and finally to empirically estimate exchange rate behavior for the Germany/U.S. case. The latter objective involved the investigation of the underlying monetary model and its variants as an explanation of the behavior of exchange rates and their implications, such as long-run purchasing power parity, overshooting and the existence of a monetary model explanation for exchange rate determination.

The historical review has pointed out that the workings of the gold standard on exchange rates caused some nations to eventually pursue monetary policies which were detrimental to their internal economies. A particular case in point is Great Britain, which, after returning to the gold standard following the end of World War I, was forced to follow a monetary contraction policy (through the Bank of England) that contributed to rather severe unemployment. Since gold was of higher price after the war relative to following the standard in the prewar years, Britain's return
to the gold standard in 1925 was in effect a revaluation of the pound against foreign currencies, reducing demand for British goods. Britain abandoned the gold standard in 1931 after the bank failures of the Great Depression. Other nations followed suit, and many nations followed policies that restricted international trade, among which was the U.S. Smoot-Hawley tariff imposed in 1930. These policies for the most part crippled the world economy, but helped shape the post-World II international monetary system, which became known as the Bretton Woods system designed to manage exchange rates.

This new system was a fixed but adjustable exchange rate system designed to capture the best of possibly two worlds, namely, the stability of the gold standard and the flexibility of floating exchange rates. However, what made the new system flexible also brought about balance of payments crises throughout the 1960s and early 1970s for many nations. The problem lay in the International Monetary Fund's (IMF) ability to devalue or revalue a currency. The IMF was created under the rules of the Bretton Woods agreement to apply such rules of flexibility in situations in which a nation that sustained a persistent current-account deficit could be suspected of being in "fundamental disequilibrium" and ripe for devaluation. However, those who held the currency of such a nation suffered great losses once the devaluation or revaluation was set in place. This
balance of payments problem reached crisis proportions in the 1960s and 1970s and added to a growing lack of confidence that the U.S. had the ability to pay out in gold for its dollars held by foreigners. By 1973, speculative capital movements became unmanageable, and a temporary response to allow the currencies of the industrialized nations to float against the dollar was made permanent after March 1973, ushering in a new era of floating and managed floating exchange rates, some of which is investigated in a study of German/U.S. exchange rate behavior from 1973 to 1990.

The objective to investigate PPP and the overshooting phenomenon suggested by Dornbusch and Driskill led to an attempt to revive the monetary model of exchange rate determination as a long-run relationship. This underlying model allows for short-run deviations of the exchange rate from its fundamentals. German/U.S. quarterly data running between the periods 1973 and 1990 was used in the analysis.

Conclusions

This latter analysis that was performed leads us to cautiously present a number of conclusions. First, there are long-run relationships of the exchange rate and macroeconomic fundamentals, at least for the Germany/U.S case. However, there is not one unique relationship. Although not unique, there does seem to be cointegration between the exchange rate and the monetary base, income and
prices. Second, overshooting occurs as a short-run phenomenon due to the significance and the sign of the first diagonal coefficient in the long-run matrix. Estimated coefficients of the relative model indicate partial agreement with the stock/flow model and less evidence for the monetary model of Dornbusch. Fourth, there are reversals of overshooting but the adjustment appears to be slow. Fifth, and perhaps more important, we do not find our estimates using the Germany/U.S. data to be in general compatibility with the strict characterization of the monetary model.

Previous work in this area has also generated similar conclusions. These unfavorable findings can be reinterpreted in light of the sequence of restricted estimations and tests which have been conducted in this present study. Cointegration between the exchange rate and its fundamentals is a necessary condition for the monetary model to hold as a long-run relationship. However, existence of cointegration is not a sufficient condition for its validity. We have proceeded with this notion in mind to first use the relative model of Dornbush-Driskill to sort out what evidence may exist for either the strict monetary or the stock/flow behavior. Then a test for the existence of cointegrating vectors was made to determine if long-run relationships between exchange rates and macroeconomic variables exist at all. A series of tests on the
cointegrating vectors and the adjustment matrix were made, following the approach of Johansen (1988, 1990) and Johansen and Juselius (1990), to determine if the German/U.S. exchange rate behavior has resemblance to a monetary behavior of exchange rate behavior.

Cointegrating vectors relating the exchange rate to its fundamentals were found but they do not strictly satisfy the restrictions that characterize the monetary behavior. This does not imply that the exchange rate is unrelated to macroeconomic fundamentals in a long-run relationship. The exchange rate does enter at least some of the cointegrating vectors. However, some evidence is provided to suggest that the exchange rate in the Germany/U.S. case is not driven by stationary deviations from the long-run relationships found. The cointegrating residual does not enter the equation representing the short-run dynamics of the exchange rate. Monetary and pricing policy apparently do not directly influence short-run movements of the exchange rate, which should be somewhat discomforting for institutions whose apparent or assumed responsibility in social planning is to manage exchange rates and trading activity in the German/U.S. case. We have found evidence for some disconnection of long-run patterns of behavior which can be changed by monetary and pricing policy and the short-run dynamics of exchange rate behavior. However, as mentioned earlier in this study, the trading sector activities of
these two nations are considerably different and have been for the course of a number of years.

The conclusions outlined should be taken cautiously. They are suggestive of a direction which needs more empirical testing. For example, more testing of specific forms of stationarity needs to be carried out. Alternative specifications may alter the results given here. Since Granger (1986) first introduced the concept of cointegration, several methods of estimating cointegrating vectors (long-run relationships) have followed. Johansen's full information maximum likelihood methods have been used in this study. This approach has allowed us to carry out inference on the cointegrating vectors with the use of likelihood ratio statistics which are asymptotically distributed as $\chi^2$, a standard test procedure. Gonzalo (1989) has pointed out that the maximum likelihood procedure outperforms other methods such as the OLS, nonlinear least squares, principal component and canonical correlation methods, and is robust to autoregressive conditional heteroskedastic (ARCH) effects and overparameterization of the lag structure. The procedure has the advantage of excellent small sample performance (relative to the Engle-Granger methodology) in determining integration and cointegration. The estimation method is robust to departures from normality and homoskedasticity. However, all the hypotheses tests are likelihood ratio tests and
strongly rely on the assumed probability distribution of the error term.

We have not carried out any analysis of the sensitivity of such tests to departures from normality and the standard $\chi^2$ tests. One would have to carry out a simulation exercise with the use of several non-normal distributions (likely the t, cauchy, $\chi^2$-normal mixture distributions and the uniform) to compare the empirical finite sample distribution of the test statistics used with their asymptotic distribution under the assumption of normality. A heteroskedastic conditional would also have to be investigated. These investigations are beyond the scope of objectives set out in this study, but do need study.
BIBLIOGRAPHY


