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PURCHASING POWER PARITY
A Historical, Theoretical, and Empirical Study of PPP
Using Traditional and Alternative Methodologies

by

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BA in Economics May 1993, VPI and State University

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Introduction

Purchasing power parity has been the object of both praise and criticism since it was formally introduced by Gustav Cassel in the early part of the century. It has been the basis of hundreds of articles and numerous books, and reserves a section in any international trade and finance textbook. This thesis attempts to define and study purchasing power parity in several forms, from the simple Cassel formulae to complex cointegration and ARIMA techniques.

This is not a be-all, end-all of the study of PPP, however. I have picked what I consider to be the most important studies of the parity condition.

The first chapter is a review of what I consider to be the most important literature, both theoretical and empirical. If I had included a review of all studies, the chapter would overwhelm the rest of the thesis. So, what I included I consider to be the most notable additions to the literature.

The second chapter is an original empirical investigation into the existence of long-run purchasing power parity. The method used is ANOVA, or analysis of variance modeling. This examination is based on two-factor analysis of the long-run means of a PPP formula over several years. This study is meant to prove the equivalence of

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means, or mean changes, in the exchange rate/price ratio. This has never been done by other empiricists. ANOVA modeling has not been used very much in any time series, because it is mainly a method to study differences in input levels for production or for differences in sales due to different strategies. However, time series modeling is not barred from ANOVA testing by any proof, so it seems feasible to test for the existence of differences in means of exchange rates and prices.

The third chapter is an empirical review of the literature. Imitations of some of the literature are made, with improvements made if necessary. One noted modification is to the productivity bias employed by Officer. Any modifications are justified by theory or by the lack of proof exerted by the test.
What is PPP?

PPP is a law of one price when it is observed to be a spatial-arbitrage argument with little or no transactions costs (Patel, 1990). Prices rise in one country relative to another, so demand for the latter country's currency will increase, pushing up the price of that currency. Cassel (1921) uses this monetarist view of inflation and demand, and Dornbusch (1976) includes asset demand for currency to enhance the parity condition. This, however, is not strictly a PPP relation, but involves the real interest (nominal, or "face value" interest rate minus the inflation rate) rate's effect on exchange rates. This, however, implies that exchange rates and prices are simultaneously determined endogenously (Patel, 1990).

Purchasing power parity, or the law of one price, suggests that in the long run, prices of "goods bundles" in one country will equal the same bundles in other countries, accounting for the exchange rate. Broken down, "Absolute PPP relates exchange rates to overall price levels. And
Relative PPP relates exchange rates to interest rates" (Hakkio, 1992) Although theory and logic suggests this to be the case, research is inconclusive about the exact nature of purchasing power parity.

Rudiger Dornbusch (1976) developed a set of theories concerning parity conditions under "perfect capital mobility, a slow adjustment of goods markets relative to asset markets, and consistent expectations" (p. 1161). Dornbusch' investigations of PPP are strictly theoretical. He does not attempt to prove his theory with data.

B. Solnik (1978) shows three other parity relationships that should be present in international finance. The first addition is interest rate parity, where the interest rate differential must equal the forward exchange rate differential, or arbitrage will take place. If exchange rates remain constant in a country with rising interest rates, foreign investors will purchase the home country's currency in order to experience the higher returns on financial investment. This arbitrage window, Solnik argues, will close quickly as demand for the home country's currency rises, increasing forward exchange rates (as well as spot rates).

The second expansion to theory in Solnik's article is forward parity. This indicates that future spot exchange rates must equal forward rates. This theory should hold because riskless arbitrage opportunities would occur if

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investors knew forward rates and future spot rates would not be equal.

The final inclusion to international finance is the Fisherian Relation. This is not a parity condition, but equates real rates of interest given purchasing power parity and interest rate parity. This is a macroeconomic theory based in utility maximization of each individual in financial markets.

Empirical tests require considerable amounts of data. Although Hendry (1986) indicates "time disaggregation" (from years to months, or from months to days, etc.) is not likely to reveal long-term relationships, econometricians prefer the power of statistical tests with a large number of degrees of freedom. The larger the degrees of freedom, the more the significant the results of tests like the F statistic, a measure of the effect of any or all of the independent variables on the dependent variable.

As a cointegrating relation, one which is exploited in recent econometric analyses, PPP is an interesting study. Arima modeling and Dickey-Fuller and Perron testing all use some type of cointegration techniques. Cointegration is a regression technique where the independent variable is regressed against time, a lag of the dependent variable, and a differenced variable created by finding the change in the dependent variable over time. The purpose of the test is to find evidence for or against a unit root, an indicator of

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series movement over time.

Balassa (1964) gives a formal, international trade definition for purchasing power parity. He makes the assumptions for a Ricardian model (one factor, two goods, and constant input coefficients), where one country (hereafter called A) has an absolute advantage in the production of both goods, but has a greater advantage in one good, which it trades, to another, the nontraded good. As included in the Ricardian model, there are constant opportunity costs (marginal rates of transformation are constant). This means country A will experience a higher relative price on its nontraded good. Through trade, as shown in the Ricardian model, relative prices will equalize. In this case, absolute prices will show parity conditions in theory.

Since money is nothing but a tool for indirect bartering, it can easily be shown, given some unity exchange rate in a two-good, two country Ricardian model, that PPP will hold. In the case of immiserising growth, when country A has some increase in its technology for producing its traded good, the relative price of that good falls, making the import good more expensive. With money included in this Ricardian model, it becomes apparent that either the absolute price of the exported good must fall, or the value of country A's currency must fall.

Balassa completes a discussion of PPP with the
following criteria that must be maintained for PPP to hold: No trade restrictions (as with many theories in international finance) and minimal transportation costs; prices equal marginal costs (perfect competition in markets), and wage differentials are equivalent to productivity differentials; differences in wages within each country are equivalent to relative scarcity; and all factors, both service and production, must be valued for accurate measurement of PPP.

The inclusion of other variables is another nuance in recent literature. Authors like Officer (1976) and Zagardo (1992) include productivity levels to attempt to find reasons for PPP deviations.

Productivity, according to Officer, is possibly an important reason for the "systematic divergence between PPP and the equilibrium exchange rate". He includes a difference between traded and nontraded goods and the GDP per capita to examine PPP variations.

Zagardo expands on this hypothesis by examining international productivity trends. Her study involves a convergence level for all countries. Productivity levels across countries, according to Zagardo's theory, will tend to move together over long periods of time. This study attempts to rationalize PPP deviations by observing productivity convergence.
A Brief History of Purchasing Power Parity

Bela Balassa (1964) gives an account of PPP theories, from simple and naive to the modern, complex econometric structures of today's literature. The beginnings were sometime during the Napoleonic wars (Harberler, 1961), but the theory was not formalized until Gustav Cassel (1918, 1921) discovered (or invented, as modern theorists imply from the lack of evidence shown to support the theory) the relation of price levels to the exchange rate.

PPP as a Predictor

The primary purpose of purchasing power parity is to predict exchange rate. This is accomplished, as stated earlier, by comparing price levels in one country with those in other countries. Identical goods should cost the same in one country as they do in the next, and so on. This of course assumes no barriers to trade, such as tariffs or quotas. Because arbitrage opportunities are assumed to be taken advantage of, any price differential with regard to the interest rate will be found and exploited until the prices are again equal. However, such assumptions are violated when one takes into account the real world.

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How is Purchasing Power Parity Useful?

"The purchasing power parity (PPP) principle has been a cornerstone of exchange rate models in international economics" (Patel, 1990). The law of one price is extremely important to those speculating exchange rates, for if the law is binding, at least long-run trends in prices can reveal long-run exchange rate trends.

Both long and short run trends in the exchange rate are very important in economic decision-making. Policy-making is both a short-term and a long-term problem. For this reason, it is important to examine ways to predict the trends exchange rates might follow for the next few days, the next few months, and for the next several years. Purchasing power parity, in theory, is a way to predict exchange rates.

For PPP to be of long-run interest to these decision makers, a country's exchange rate must move toward its PPP rate over time While the dollar might vary from its short-run PPP rate, it must move toward its PPP long-run rate.

Hakkio (1992) examines the movement of actual and PPP exchange rates over long periods of time. These two rates tend to move together in the long run. While the dollar rose and fell opposite to its long-term trend in the short run, greater spans of time showed the dollar to move with its long-run PPP rate.
Both businesses and governments would also like a short-run guide to exchange rates. However, market exchange rates do not move together from day to day, or even month to month, as they do over long periods of time (Hakkio, 1992). Hakkio found PPP unreliable in the short run for determining yen/dollar relationships. Fung and Lo (1992) include other implications of the holding or lack of holding of purchasing power parity for business. If PPP does not hold, exchange rate changes can affect the value of a firm. Managers of the firm must be aware of exchange rate fluctuations and consider their economic exposure to such changes.

Strict holding of PPP in the short run is extremely ludicrous, as predicting policy shocks is as difficult as predicting the winning lottery numbers. Policy-change announcements can instantly affect the exchange rate, but prices tend to be sticky and fairly rigid. So, in the short run, large violations of PPP can be seen, leaving exchange rate forecasts based on PPP holding a little shaky.

Stringent tests of PPP may not be the answer in the short run. The margin of error in predicting the PPP exchange rate in the short run is 10 percent (Levich, 1985). Also, Hakkio (1992) argues there might be a "zone in which PPP forces are weak." Times of political and economic disarray are examples of periods in a time series where PPP could fail to hold for a short time. Perron (1988) looks at
these "structural breaks" in examining PPP.

Forecasting exchange rates using PPP would only be effective if exchange rates prove to be a stationary time series. If the exchange rate is a nonstationary series, not even major empirical support of PPP could give support to PPP forecasting.

The Unit Root

"Testing for stationary in the autoregressive representation of a time series amounts to testing for the presence of unit roots" (Doukas and Rahman, 1987). A necessary step in analyzing differences in PPP conditions is to look for the presence of unit roots. Unit root testing is used to examine movements in a time series. Random walks in time series is a concern to econometricians because ordinary least squares estimation would not provide consistent estimators (Pindyck and Rubinfeld, 1991). A technique called first-differencing could yield a stationary series (shown in chapter 3). First-differencing would reveal whether the series was actually stationary or followed random movements. In differencing, tests of the critical value of the lagged variable of the coefficient is tested, but the null hypothesis is different than in normal OLS modeling. The null hypothesis testing for unit roots is that the coefficient is one, not zero. A Dickey-Fuller test
would determine the results of this hypothesis test. If the null hypothesis cannot be rejected, a unit root cannot be rejected, so the series cannot be proved to be stationary. This has a detrimental effect on purchasing power parity testing.

The presence of a unit root in PPP analysis indicates that parity conditions would not hold (formally tested in chapter 3). Coughlin and Koedijk (1990) are two of many authors in recent PPP studies that have attempted to determine the presence of unit roots in PPP series. The existence of a unit root in a time series concerning exchange rates and prices indicates the real exchange rate is nonstationary. Because PPP requires a stationary series, if there is no unit root, the parity conditions do not hold (Flynn and Boucher, 1993).

Kim (1990) uses the cointegration approach to determine the existence of a unit root. Cointegration in standard econometric research is similar to ARIMA modeling, discussed later. Differencing of a time series can produce a stationary series.

Unit root tests are used when analyzing both standard models of PPP determination, and with Perron analysis, looking for a structural break in a time series (Perron, 1988) With standard models, the data is examined as a continuous time series. By contrast, with Perron testing, the series is broken into at least two segments, one before
the break occurred, and one following the structural break. The results indicate whether a policy shock has any effect on PPP conditions.

Flynn and Boucher (1993) develop a Perron model with cointegration and three structural breaks. The first structural break is the closing of the gold window in August of 1971; the second is the Fed change in operating procedure in October 1979; and the third is the Plaza accord in September of 1985 (an empirical look at the Perron test with the last two breaks is shown in chapter 3).

In testing for unit roots in a multivariate model, it is necessary to test for unit roots in each variable in the time series. If all indeed indicate a unit root, the empiricist may conclude the variables are nonstationary.

Perron (1988) cautions against concluding a unit root in a time series that contains a structural break, because "unit root behavior mimics the behavior of a stationary series that contains a structural break" (Flynn and Boucher, 1993).

Perron (1992) also considers structural breaks when the date of the break is not known. This, however, requires minimal coefficient statistics for possible breakpoints. The reason for the structural break cannot be determined from testing, and the test's power is not strong enough to prove the existence of such a break without proof in theory.

Also included in recent testing is the "near unit root"
(Dueker, 1993). In strict unit root testing, PPP can hold if the time series reverts back to its long-run mean after a shock, but not if the series contains a unit root. Dueker includes long-memory models, which show a long-run reversion to parity conditions even if a unit root is found. These long-memory reversions are the scourge of unit root theorists, because unit roots cannot be proved to be nonexistent in long-memory time series. This criticism of unit root testing leads to more sophisticated and far-less researched PPP modeling: the ARIMA model.

**Criticisms of Unit Root Testing**

The main criticism of unit root testing is in the assumption of homoskedasticity (constant variance of error terms) (Evans and Savin, 1981). Because the potency of unit root tests is influenced by the assumptions of an ordinary least squares model, the test for the coefficient of the autoregressive variable is affected by the mean and variance of the error term. Also, Evans and Savin show that as mean increases or as variance decreases, the power of unit-root tests increases. Hence, the more efficient the model, the more effective the unit root test.
The ARIMA Model

Arima, or AutoRegressive Integrated Moving Average modeling, has been featured in several new additions to the literature, namely in Dueker (1993) and in Enders (1988). Various types of ARIMA models are discussed.

Enders tries to find the "best" ARIMA models, but restricts himself to much of the existing theory. The author uses the restricting ARMA model, leaving out any type of differencing (known as integration or cointegration) to attempt to find a stationary series. If a unit root cannot be proved to be absent from the time series, differencing can be used to make a series stationary. Enders does not attempt to difference the model, so if the series is not stationary, the test results are ambiguous and inconclusive with regard to purchasing power parity.

Dueker applies ARMA models to differenced series, resulting in a more conclusive result. Because the ARMA model is integrated to order one (first-differencing), the results yield more information to the true nature of the time series. The differenced series will show a tendency for mean-reversion if the coefficient for the integration is less than some value. If this mean-reversion is existent in a differenced series, according to Dueker, there is evidence of long memory. In this case, tests for the unit root cannot provide significant results indicating a stationary
series, and therefore cannot justify the existence of PPP. However, with ARIMA modeling, a time series can exhibit long memory, and therefore PPP can be shown to exist in the long run.

**Reasons for PPP Deviations**

Grilli and Kimiski (1991) have concluded that the random walk (nonstationary) behavior of the real exchange rate could depend on the historical episode being investigated. A long time series with no historical breaks will almost definitely cause a nonstationary series. Looking at time series with no understanding of the time in which the data occurred would be inconclusive.

Short-run tests do not show any evidence for the existence of PPP, because tests involving only small time series are not powerful enough to overcome the presence of unit roots (Glen, 1992). However, in the medium-run, as Glen calls the time between the short and long run, evidence shows a moving together of exchange rates and price levels. This would imply that short-term shocks would have a serious effect on parity, but after the shock, the market would shuffle and scurry to bring back the law of one price.

Dueker (1993) gives reasons for deviations from PPP. These four possibilities are: barriers to trade such as tariffs and quotas; different consumption preferences across
countries; the inclusion of non-traded goods in price indices; and sticky prices.

The second of Dueker's possibilities is intriguing. Should people's preferences be different across countries, as they should be, price changes of certain items would indeed affect PPP conditions. A price change on a preferred item (a normal good) would affect PPP relationships in a different way than would a nonpreferred good (an inferior good).

Miller (1993) looks at long-run deviations from PPP. His findings are that the long-run equilibrium is violated if a monetary shock occurs with sticky prices. In this instance, the exchange rate would be affected, but prices would not change to ensure purchasing power parity. The result would be a current account imbalance that would cause PPP not to hold in the long run as well.

Conclusions of the Literature

Researchers have come to different conclusions when dealing with purchasing power parity. As a long-run guide to the dollar, PPP exchange rates have been found to move concurrently with actual exchange rates (Hakkio, 1992).

However, as a short-run beacon, PPP exchange rates do vary from actual exchange rates. Both political and economic shocks can cause the exchange rate and price-level
differential to move in different directions.

Barry Solnik (1978) suggests a derivatives approach to parity conditions. If the PPP condition, and the other parity relationships, are unbiased predictors of exchange rates, there should be no measurable risk factor involved in forward exchange markets, for the ability to measure interest rates and price levels should prove to be an effective forecast of exchange rates. But, if there are deviations from purchasing power parity, there should be risk premia attached to forward exchange transactions. The buying and selling of these risk premia will, in effect, cover any obvious arbitrage opportunities that could arise from PPP deviations.

Dornbusch (1976) concludes the time path of exchange rates depends on, among other things, price elasticities. Combining interest rate and purchasing power parities, in the short run, if interest rates rise, prices will rise due to the depreciating exchange rate, but proportionally to price elasticities. In this case, indirectly, purchasing power parity will hold.

In unit root testing, Adler and Lehman (1983) and Grilli and Kaminski (1991) have found a unit root in real exchange rates in time series from the post-World War II era. This would imply PPP does not hold as a long-run condition because the series is nonstationary.

Flynn and Boucher (1993) heed Perron's warning about
unit roots imitating a structural break, and consider structural breaks when testing for unit roots in the time series. Their explanation for the apparent lack of long-run PPP is that there are time-varying factors that are omitted from the relationship of prices to exchange rates. Another explanation could be that the structural breaks that were tested were not the only structural breaks to be considered. Smaller time series, as the ones tested with the structural break hypothesis could themselves contain structural breaks, which, in turn, would be imitated by the presence of unit roots.

Since unit roots were indeed found for the exchange rate (Flynn and Boucher, 1993), Patel (1990) would conclude that even strong evidence of PPP would not improve forecasts of exchange rates. Patel challenges all exchange-rate speculators to find support for their predictions based on PPP analysis.

Kim (1990) uses cointegration to test for PPP. The results, while indicating significantly that some time series examined lack a unit root, and are therefore stationary, cannot show with any significance a stationary series between price levels and the exchange rates between USA and Japan, England, and Canada. This seems to be a serious problem, because these are three of the United States' major trading partners. This means testing for PPP is not effective, and forecasting exchange rates based on
price levels could not be trusted.

Fung and Lo (1992), while looking at their cointegration technique for finding the time path of the random walk, found that government policy might help to maintain PPP. Their literature is for firm management, so their advice is for firm managers to avoid PPP predictions for exchange rate hedging in the short run, and to minimize exchange exposure. Exchange rates cannot be predicted in the short run by price levels.

ARMA empiricists have been the most successful in recent studies for determining somewhat stationary series. Enders (1988) found shaky evidence for the existence of PPP for major trading partners of the U.S. However, a random walk behavior cannot be rejected, so any tests for purchasing power parity are not significant.

Dueker (1993) finds a little more support by expanding the ARIMA model for integration. This is a case for long memory, and therefore long-run PPP. The results are that even though the results indicate a possibility of the existence of long-run purchasing power parity, the results are, again, not significant enough to emphatically support the law of one price.

Balassa would argue with all of the so-called empiricists of recent years, because these later econometricians have yet to find a way to determine the existence of long-run PPP. Balassa's reasoning would be
that these critics have yet to cover all the bases. The four added assumptions that Balassa either states or implies are not met with recent econometric analysis. Most researchers (including the writer) fail to include all the data required to form a complete PPP model.

Officer (1976) has read Balassa, for he does attempt a more complete model, including productivity for the manufacturing sector in his productivity bias model for determining relative PPP.

A variable notably left out is a "productivity" variable for the service sector. The only real proxy for the service sector is inputs, which cannot reasonably be used, as the model requires output of all sectors, manufacturing and service.

The results of productivity bias testing show a lack of empirical foundations, meaning the theoretical foundations might also be faulty. However, the theory that productivity inequalities among countries have an effect on relative PPP is maintained by the author. Chapter three further investigates the productivity bias, with different theories concerning international trade and finance.

Unfortunately, theorists and empiricists differ in their opinions of the existence of purchasing power parity. Theorists like Cassel (1920) and Lee (1976) maintain the PPP doctrine, including the law of one price. Mathematical and intuitive proofs give by the previous authors and others
seems a difficult thing to disprove. The belief that price levels have an effect on exchange rates seems logical and the math proves solid (Dornbusch, 1976), so empirical proof seems simple to accomplish. However, evidence of empiricists like Perron (1988), Flynn and Boucher (1993) and others, seems to disprove any theories concerning the existence of PPP. The existence of a unit root The following chapters provide further empirical analysis ranging from the original (ANOVA modeling in Chapter 2), to re-investigating present research and reworking some empirical models (Chapter 3).
Long-Run Purchasing Power Parity

An ANOVA Approach

Introduction

"Analysis of variance (ANOVA) models are versatile statistical tools for studying the relation between a dependent variable and one or more independent variables" (Neter, et. al., 1990). ANOVA models are different from standard OLS models in that they do not assume any specific nature of the relationship between the dependent variable and independent variable. Of course, in OLS models, the assumption is that the relationship is linear. ANOVA models, on the other hand, do not assume this relationship, nor do they require independent variables to be qualitative.

Anova is a very general test that can give insights into the existence of long-run purchasing power parity. ANOVA models test for equivalence of means over the qualitative variables. From theory, if the means are equal, PPP can be maintained. If the means are different, PPP cannot be affirmed.
Of course, statistical theory states that an acceptance of the null hypothesis (in this case, the means are equal; PPP holds) is not as strong as a rejection. A rejection of long-run PPP is a strong statement: it goes against theory that the law of one price does not hold. If, in the long run, PPP fails, then there should be a long-term arbitrage window that will never close. There are several reasons why PPP might fail (see Dueker, 1993). If any of these events occur, the theory of parity of prices and exchange rates cannot be maintained.

The models in the following chapter are from two-factor analysis of variance. The two factors are: and quantitative independent variable and a qualitative dependent variable, with two factor levels. The tests will determine whether the averages of two levels of the independent variable are the same over a given period of time.

Tests were performed on certain parity relations between the United States and Japan. Japan was chosen because it is one of the United States' major trading partners.

The data required to perform these ANOVA models are: the Japanese-US exchange rate, the wholesale price index for Japan; and the WPI for the United States. The wholesale price indices were used because firms are more likely to be aware of fluctuations in the exchange rate, and prices of wholesale goods tend to be more tied to the exchange rate.
The WPI is also used because of its strength in the literature (Kim, 1990).

Monthly data was gathered in International Financial Statistics for the years 1978 to 1990, a time of flexible exchange rates.

The ANOVA Model

The purpose of the ANOVA model, like the OLS models, is to minimize means square error (MSE). The quantity to be minimized is:

\[ Q = E_i E_j (Y_{ij} - M_i)^2 \]

where \( Y_{ij} \) is the jth value of the ith factor corresponding with the dependent variable, and \( M_i \) is the population mean. An assumed unbiased estimator of \( M_i \) would be \( Y \). When MSE is minimized, the fitted values are the best estimates of the actual values to be estimated (Pindyk and Rubinfeld, 1990).

There are four tests of purchasing power parity in the following chapter, but they all follow the same statistical model.

\[ Y_{ij} = M_i + e_{ij} \]

The tests are to determine whether PPP is found to tentatively hold in the long run.

The first model examines a certain relationship of prices to the exchange rate. The means of a ratio of

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exchange rate to prices in the United States is compared with the means of a ratio of the exchange rate to prices in Japan. The results are listed in figure (2.1).

The results do not seem to be very supportive. This does, ironically, support PPP. Both of the relations show the exchange rate multiplied by the price levels of the two countries. If this situation were to hold, the exchange rate could be removed as a constant, and then only price levels would be left to be compared.

The second model, shown in figure (2.2) show the relationship of the mean of the sum of the exchange rate to the mean of the sum of its previous value. This seems to be an obvious relation, but one that needs to be modeled. Of course, the value and its lag-value are extremely similar, since only one variable differs for each of the summations, and in long time series, one value that differs will not cause a large change in the value of the estimate.

The third model is a comparison of a form of the Cassel formula: Exchange rate * (WPIJapan/WPIUSA), to the spot exchange rate. This result is quite interesting. From the results in figure (2.2), There can be found no evidence contradicting the existence of this form of long-run purchasing power parity.

The normality assumption of the data is violated, and the PROB>0 statistic implies, but with a Kruskal-Wallis rank examination, non-normality does not affect the results of Clendenon, 27
the normal ANOVA test (see the Chi-square p-value). From the Tukey comparison at 90% confidence, the difference in the means does not stray from zero. It is found that the confidence limits allow from 8.7 points (yen per dollar) below the exchange rate to 11.8 points above with a 10% significance. This is remarkable considering the lengthiness of the time series.

The final ANOVA model is meant to strengthen the previous model. It examines the percent changes of the exchange rate and the price level differential over the time series. This model is extremely conclusive about the existence of long-run relative purchasing power parity.

Results from the Tukey comparison show a failure to reject equal means for the two values at a 90 percent confidence interval. There has been an average .26 percent increase in prices per month for the 12-year period, and a .39 percent increase in exchange rates (per month). According to the Tukey comparison, this is not a great enough distance to reject the null hypothesis that changes in price levels equal percent changes in the exchange rate. This is an important revelation given the recent pessimism regarding the existence of long-run PPP. The results of the ANOVA model indicate long-run relative PPP, a result that recent empiricists have found hard to prove.

Because the tests do not indicate any evidence to reject the theory of purchasing power parity, then the

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theory must be accepted until real proof is shown that differences exist between changes in price levels and exchange rates.

Conclusions

The results of ANOVA modeling indicate the existence of long-run relative PPP (Figure 2.4), and even imply the existence of long-run absolute PPP (figure 2.3). This is a feat considering the recent studies finding no basis for either. ANOVA models are not restricted to finding linear relationships between a dependent variable and its independent variables, so the results can be interpreted in different ways than standard linear regression models.

The next chapter attempts to strengthen the ANOVA results with other empirical proof of the existence of long-run PPP. Because the ANOVA model implies there is not enough proof to deny the existence of long-run purchasing power parity, there should be other tests that can confirm these results. Even if other tests cannot find conclusive proof that PPP exists in the long run, ANOVA modeling can be used to refute anything but definite proof that PPP fails as a long-run relation.
Purchasing Power Parity

An empirical study of PPP between the U.S. and Japan in a floating exchange rate system

The theory of purchasing-power parity states that the exchange rate is determined by the price level of domestic currency compared to the price level of foreign currency (Officer, 1976). Theoretically, for arbitrage opportunities to be closed, a change in a country's price level must be accompanied by an inverse change in the exchange rate. PPP is the term for the equation:

$$ P = E P' $$

where $E$ is the exchange rate of the given country, $P$ is the price level of the given country, and $P'$ is the price level of the "foreign" country (Caves, et al., 1990).

This paper will be testing purchasing power parity as a long-run condition, focusing on the American dollar and the Japanese yen. The data will focus on floating (or "dirty" floating) exchange rates.

The Data

Using data from the International Monetary Fund's *International Financial Statistics*, the real exchange rate
for the United States in relation to Japan was constructed. Monthly data was accumulated from 1978 to 1990 and was transformed into 1985 as a base year. The components of the real exchange rate were the wholesale price indices for the United States and Japan, and the dollar price of Japanese currency. The choice for the wholesale price index rather than the consumer price index is from the assumption that large firms will be more reactive to small price level fluctuations than the general public. If the price level in the United States rises, firms in the U.S. will seek to buy their input goods in other countries. This demand for foreign exchange will increase the price of the foreign currency. Hence, the rise in U.S. price level will increase the price of foreign currency, making foreign goods more expensive, hence purchasing power parity.

Another reason for using the wholesale price index over the consumer price index is its apparent strength regarding testing in the literature (Kim, 1990). The nominal exchange rate has been found to be more strongly cointegrated with the WPI than the CPI.

Japan was chosen because it is one of United States' major trading partners. Price level changes would be felt more dramatically by a country that trades heavily with the country where the price level takes place than a country that does not rely on the other country for trade.

The predicted outcome, according to theory, is that in Clendenon, 31
the long run purchasing-power parity will hold, even if short-run shocks can skew the system for a finite period of time. Some of the techniques that will be discussed are maximum likelihood ARIMA modeling, Dickey-Fuller, and Perron, but focusing on the basic model as interpreted using Cassel's formulae:

$$e_t = \frac{P_t}{P'_t}$$

and

$$e_t = \frac{e_{t-1}(P_t/P'_t)}{(P_{t-T}/P'_{t-T})}$$

(Lee, 1976). P's and Pf's are price levels of the given and foreign countries, and t and T represent current periods and the base period. Criticisms of these formulae will be discussed and evaluated.

PPP, or the law of one price, assumes negligible transactions costs (Patel, 1990). A problem can be foreseen to arise because in the real world transactions costs are usually far from negligible. This paper will assume away transactions costs knowingly, and focus on Cassel's monetarist modeling.

Cassel's models need no regression for "eyeball" prediction. Figure (3.1.1) shows the values of the second model on the right, and the actual values of the exchange rate on the left. It is easily seen that the figures are fairly close consistently throughout time, using a lag of 1. Plots of both models also show the relationship between price levels and the relative exchange rates {figures Clendenon, 32
Forecasting the exchange rate or the price level is the primary reason for this theory, so the models must be accurate in predicting the future exchange rates or the price level. The way the model is set up is for predicting the exchange rate by using a time lag. Predicting future values of the approximated model are very accurate in the short-run, so it would seem that the model is appropriate for forecasting (see figure (3.1.4)).

Regression of the prediction equation shows a very high goodness of fit (figure (3.1.5)). This proves that there is a linear relation between the actual relative exchange rate and the predicted relative exchange rate with one time lag. These results are important because it proves prediction of future relative exchange rates is possible.

This model's high degree of fit means that the PREDE equation follows the ERATE values, implying that short-run PPP holds, but offering no proof that the price/exchange rate relation converges over time (figure 3.1.6). In actuality, the goodness of fit will not show a short-run relationship if the series contains a unit root (Flynn and Boucher, 1993). The graphing of the relationship shows a random walk in the data, possibly with a drift. The similarity in the two graphs does show that the two are related, however. This means that a short-run prediction would be accurate for a price/exchange rate forecast.
It is also interesting to compare the exchange rate to the exchange rate in the previous period. The results show a high goodness of fit (figure 3.1.7), so adding the additional information might not affect the ability to predict exchange rates, but being able to predict the exchange rates with this model could affect the ability of predicted exchange rates to forecast future prices. In later sections of the paper, the nonstationarity of the series will be tested to determine if other variables, like the price level differential, can have an effect on the independent variable.

The ARIMA Model

Walter Enders (1988) tested purchasing power parity using the ARIMA technique for alternative exchange rate systems. Using data from both before and after the Bretton-Woods demise, Enders compared US price level and exchange rate with several other countries. Enders found that he could not disprove that the predicted steady-state values of the real exchange rates deviated from unity.

The Econometrics

Enders began with the basic econometric model of

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relative purchasing power parity:

\[ e_t \cdot P_t - aP_t = dt \]

where \( dt \) is the stochastic disturbance (deviation from PPP) and \( a \) is a constant. Long run purchasing power parity will hold if \( a = 1 \) and the \( dt \) series is stationary.

When using the ARIMA modeling technique, Enders rearranged the equation to be:

\[ e_t \cdot P'_t / P_t = a + dt \]

Enders merely rearranges the variables so that the "real" exchange rate is on the left side of the equation, and the constant term and the stochastic disturbance are on the right. From this form, Enders uses the Box-Jenkins ARIMA technique to estimate \( a \) and to characterize the stochastic disturbance.

**Results**

The results in the Enders paper points to a second order process for the autoregression. In the data for this paper, there were also signs pointing toward a second-order process (figure 2.1) The results are very significant for the first order and also significant for the second order. The results show the autocorrelations dying off very slowly, so a moving average test does not seem necessary. Enders says that ARIMA modeling shows mixed support for PPP because the real exchange rates are convergent, but the confidence
intervals are large enough that "a random walk cannot be rejected" (507). Prediction when the time series is not stationary would be very risky, as shown in figure (2.2).

The Dickey-Fuller Test for Unit Roots

The Flynn and Boucher article (1993) uses alternative methodologies to test long-run purchasing power parity. The specification for the unit root test is:

$$X_t = \alpha + \beta_1 X_{t-1} + \delta t + \gamma_1 D(X_{t-1}) + \epsilon_t$$

where $X$ is the exchange rate or the Japanese-United States' price level differential. The test is to determine whether or not there is a time trend or a unit root.

In applying the Dickey-Fuller test to examine PPP, the "forward" cointegrating regression, as specified by Flynn and Boucher:

$$e_t = \beta_1 + b_2 (p_t^\prime - p_t) + z_t$$

where $e$ is the nominal exchange rate, $(p_\prime - p)$ is the Japanese-United States' price level differential, and $z$ is the regression residual. The Dickey-Fuller cointegration test is a test for a unit root on the residual:

$$z_t = \gamma + \rho z_{t-1} + \delta D(z_{t-1}) + \omega_t$$

with lagged values to correct for any serial correlation. Flynn identifies this test specification as the Augmented Dickey-Fuller (ADF) test.

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Results

Using the data, the Dickey-Fuller test was performed using the adjusted $f$ statistics and comparing them to a Dickey-Fuller table. The results are as follows:

Ordinary least-squares estimation could not be used for the model because testing the $t$-statistic for the growth coefficient would be biased toward zero, and the test would be whether or not the coefficient was one, so the results would not be applicable (Pindyck and Rubinfeld, 1991).

From the unrestricted and restricted regressions the adjusted $f$ statistics are calculated (figure 3.3.1). $ADJFTST1$ is the statistic for testing the exchange rate for a unit root, $ADJFTST2$ is the statistic for testing the price level, and $ADJFTST3$ is the statistic for testing the lagged values of the first-difference of the cointegrating regression. The test on the $ADJFTST3$ is called the Augmented Dickey-Fuller test. The ADF test examined is the test with 12 lags, from Flynn's test of the $Q$-statistic.

For the $ADJFTST1$ and $ADJFTST2$ were tested for a unit root, and were both found to have unit roots in the first order, but Flynn reports finding no unit root in the first differences. The first-order unit root test from the results of this paper and the rejection of a unit root from first differencing in the Flynn paper would suggest the presence of a unit root.

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In testing for the ADF, one would use the ADJFTST3 variable. In testing for the presence of cointegration, the results found give no indication of the ability to reject the null hypothesis of no cointegration. Therefore, Flynn states, PPP does not hold as a long-run relation.

The Perron Test

The Perron test is a result of Perron's assertion that a unit root behavior may be imitated by a series with a structural break. This, Flynn states, is an important criticism of recent studies of purchasing power parity. A structural break may not be realized if the data is examined as a whole, but by breaking up the data set, Perron states, the unit root behavior may be tested among the separate breaks. The Perron Test is derived from the regression as follows:

\[ X_t = M_1 + Bt + (M_2 - M_1)DU_t + v_t \]

\[ v_t = a + p_1v_{t-1} + y_1D(v_{t-1}) + u_t \]

where \( X \) is the exchange rate or the price level differential, \( t \) is the time trend variable, \( DU \) is the intercept dummy variable that breaks the data in relation to the structural break, and \( v \) is the residual or detrended value of \( X \).

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The Perron Test is an application of the Dickey-Fuller Test on the detrended variable \( v \). Critical values of the detrended variable, however, are different from the Dickey-Fuller tables.

Results

The test was run with one structural break, integrating the Plaza Accord in September of 1985. This event was a move to devalue U.S. currency against other, key currencies. This, Perron states, could produce a structural break in the time series. A structural break, according to Perron, can cause a time series model to imitate the presence of a unit root. Regressions were run on the original equations, and for the residuals to find the \( f \) statistics for the restricted and unrestricted series. The adjusted \( f \) statistics are found in figure 3.3 as \( \text{ADJFTST4} \) and \( \text{ADJFTST5} \) for price level and exchange rates, respectively. The results from the Perron tables are as follows: One cannot reject the null hypothesis that either the time-trend variable or the dummy intercept, or both have an effect on either the exchange rate or the relative price level. Therefore, Perron concludes that one cannot accept PPP as a long run relation in itself, because one cannot say that outside shocks or time itself has an effect on the relationship between prices and exchange rate.

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The Productivity Bias

Lawrence Officer has criticized the purchasing power parity theory of exchange rates.

It has been shown that the imperfections of PPP theory fall into two categories: (1) those that reflect the fact that the PPP theory is subject to random error in its predictions; (2) those that emphasize the role of variables other than price levels in exchange rate determination; and (3) those that involve the hypothesis of a systematic bias in PPP as a measure of the equilibrium exchange rate.

Officer claims that the most important reason for the current fallibility of PPP theories is their failure to realize the productivity differences among countries.

Officer's econometric analysis includes a new variable, that he calls PROD, or productivity difference among countries. His math is as follows:

\[ \text{PPP/R} = a + b\text{PROD} + e \]

He uses only OLS, assuming e to be distributed normally. The productivity bias is accepted if the estimate of B is significant. His hypothesis also predicts a positive bias for productivity. His testing could not prove the existence of a productivity bias, but only because it might need improvement. Officer says this theory is "questionable" on analytical grounds because it does not account for

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inequalities in nontraded goods. In a society where service is the highest-growing industry, there should be, integrated into the model, a variable that accounts for nontraded commodities.

The error could be in Officer's setup of the model. Officer precedes the theory of Dueker (1993) that PPP deviations could be explained in part by the presence of non-traded goods in price indices. Part of Officer's model attempts to differentiate traded goods from those that are not traded in the open market. This would indeed be effective in the two country, two good model described by David Ricardo. However, in a modern society, comparative advantage and economies of scale are indeed present in the international goods market. Price levels of all goods, even if some of those goods are not traded explicitly, should be included in PPP studies because all goods can be called "potentially tradeable."

This design can be founded on the Heckscher-Ohlin model of international trade described in Husted and Melvin, 1993). With increasing opportunity costs in goods sectors (stereotypically defined as "capital" goods and "consumer" goods), at different price levels, a country might find itself importing goods it previously produced at home, and exporting products it had previously imported.

Officer, sticking to an antiquated international trade theory, is not only probably incorrect in his modeling, but
also includes an exorbitant amount of unnecessary work to find traded and nontraded goods' price indices. As stated in chapter one, the Hecksher-Ohlin model allows for potentially traded goods as well as for pre-existing traded goods. Through economies of scale, increasing opportunity cost, and comparative advantage, one cannot assume that at all price levels, exported goods will not change to imported goods, and vice versa. This means that all goods must be considered in the productivity bias.

Officer looks at the productivity of only manufactured, exported goods, and removes nontraded goods by division. How can Officer be so Godlike in his exclusion of such a large section of manufacturing? He removes data that, according to the Heckscher-Ohlin theory should be included, because with economies of scale, not every type of a particular good can be produced by one country, so specialization can occur within markets as well as between markets. Even what are currently nontraded goods can be included in modeling the productivity bias because of this assertion.

Figures (3.4.1, 3.4.2, 3.4.3) seem to support the existence of productivity differences between Japan and the United States. Figure (3.4.1) shows the productivity increase in the two countries over 12 years. Figure (3.4.2) compares percent changes in productivity by month. This figure shows Japanese productivity has been very volatile,
jumping up to 4 percent by month and dropping by the same ratio in other months. Figure (3.4.3) shows Japan dominating the United States in productivity in later years. All three of these graphs give proper reason to test the effects of productivity on international financial markets.

The first tests are regressions of productivity on price indices. This is to test whether changes in productivity have an effect on prices. Figure (3.4.4) shows the productivity level of Japan has a linear relationship with the WPI of Japan, but the low R-square indicates not much of the model is complete, hence, the productivity level of Japan does not reveal very much about the true nature of the country's price level.

On the other hand, figure (3.4.5) does show a linear relationship between the productivity level of the United States and its price level, plus the R-square is high (.549), meaning the productivity levels have a descriptive impact on results on the price level of the United States.

Figure (3.4.6) is a model similar to Officer's productivity bias model, except that the variable corresponding to productivity is a ratio of Japan's productivity level and the productivity level of the United States. Officer's productivity bias model takes out productivity of nontraded goods, and fails to take international advantage into account when setting his model. This could be the reason for his failure to find a
significant result to his tests.

The results of the international productivity bias model show that changes in productivity ratios do tend to explain movements of the real exchange rate (exchange rate * the WPI of Japan/Wpi of the United States). This could account for a loss of relative purchasing power parity, because changes in the productivity ratio seem to have an effect on the real exchange rate (PPP rate).

Officer follows the advice of Balassa, and explores new variables to determine if they have a descriptive effect on the real exchange rate. However, Officer fails to take some things into account. His adherence to a Ricardian international trade model leaves out the possibility of potentially traded goods because the Ricardian model assumes complete specialization in production.

Officer also fails to recognize international productivity differentials, which can lead to a leaning of the real exchange rate toward the productive country (see figure (3.5.6)).

Conclusion

Just by looking at the regression of exchange rate on relative price levels, one seems to see a highly-linear relation between exchange rates and price levels. The $R^2$ is extremely high, and predicted values seem to be significant.
From these results, it appears that forecasting should not be a problem with the basic PPP model.

Many econometricians disagree with the validity of this statement. Walter Enders uses ARIMA modeling to examine any potential problems with forecasting. Because Enders could not reject the possible random-walk behavior of the data, prediction of future exchange rates or price levels would be useless. This is seen in the forecasting results given by maximum likelihood ARIMA forecasting.

However, Flynn and Boucher consider the fact that prices and exchange rates merely follow a time trend, that price levels and exchange rates rise over time. Using the Dickey-Fuller test, it has been shown that both exchange rates and price levels contain a unit root that disappears in the second differencing of the data. Flynn and Boucher report Perron's assertion that with a structural break, the data can imitate a unit root. They also tested for PPP using the Perron test, and this paper also attempted to apply the test. The test was for one structural break, the Plaza Accord of September, 1985, and found that long-run purchasing power parity does not hold for the Yen, because the results of the tests could not reject the possible effect of a time trend, even within a structural break.

Officer begins to add other variables into the PPP equilibrium model, additions that he seems to renounce in the beginning of the paper, but additions that are advised.
by Balassa. He adds a variable he calls productivity and regresses real exchange rates on that variable. This is an attempt to bring the long-run PPP caveats out and solve for them. His theory did not pass empirical testing. As the old saying goes, however: an economic theory was never thrown out because of bad results. Officer quickly states that PPP must pass positive tests rather than fail negative ones.

However, the productivity bias test with certain modifications does seem to give evidence for measurable deviations from PPP. Changes in productivity ratios between countries appears to have an impact on the real (PPP) exchange rate.

Actually, with the data involved, if it were not for others' assertions that PPP failed as a long-run relation and the use of their accepted tests, PPP passed as a long-run relation in its most basic form, the Cassel formulae. It is possible to see the existence of PPP and its effects in the long run. Flynn and Enders are skeptical about using PPP as a long-run relation, but possibly this area of econometric time series analysis should be further examined. None of the results equivocally denies the long-run relation of prices to exchange rates, but merely "fails to accept" it. The results on the Cassel formulae indicate a failure to reject the positive linear relationship between prices and exchange rates.
Conclusions

The original work in this thesis contradicts other empiricists' work by indicating the presence of long-run PPP, or at least long-run relative purchasing power parity.

The ANOVA model, by being a more general model not restricted to a linear relationship, gives results indicating long-run relative PPP by proving long-run means of the percent-change of the price level differential and the percent-change of the exchange rate between the United States and Japan. These results insinuate changes in the price level are, in the long run, mimicked by changes in the exchange rate. This is a breakthrough in PPP investigations, because very few have been able to show any definite relationship between price and the exchange rate, and no empiricists have yet attempted the ANOVA model in PPP studies.

In the other original work, PPP was shown to be affected by a manipulation of Officer's productivity bias. The research of Officer was changed because some of his variables were constructed for a limited, Ricardian international economy. The new variables were shown to influence PPP values. These results shed new light on deviations from long-run PPP by giving a possible reason for the anomalies in time series dealing with PPP.

The results of the re-investigations into other

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empirical tests were inconclusive, however. While seeming to be a disappointment, this could actually be a blessing in disguise if this ANOVA modeling attracts the attention of time-series econometricians because realizing the shortcomings of ANOVA modeling and focusing on the advantages, this type of empirical work can be of great importance to researchers investigating any of the parity conditions of international finance. Because ANOVA tests the hypothesis that mean values are equal, parity conditions are able to be tested by analysis of variance techniques. The anticipated result for proof of parity conditions is that there are equal means, which is a result that is meant to be rejected in most ARIMA tests. However, there are no modifications that need to be made for applying this test to parity models. Unlike testing the F statistic for independent significance of specific variable for a unit root (Dickey-Fuller and Perron), there are no tricks to be made, no complicated tables for changing the null hypothesis of the test. Only the result should be different: instead of rejecting the null hypothesis that means should be different, the hypothesis should be accepted if parity conditions hold.

Chapter 2 reveals that even though recent time series modeling cannot find proof for the existence of PPP, other models that do not employ the standard time series restrictions are able to discover long-run parity

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conditions. These are significant results, as recent testing finds PPP evidence shaky.
Figure 2.1

Results of the ANOVA model

Dependent Variable: Exchange*Price
Source: Country (Japan, United States)

<table>
<thead>
<tr>
<th>Source</th>
<th>Pr &gt; F</th>
<th>Pr &lt; W</th>
<th>Normality</th>
<th>Mean-Japan</th>
<th>Mean-USA</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>0.0004</td>
<td></td>
<td></td>
<td>186.28</td>
<td>210.4</td>
<td>24.118</td>
</tr>
<tr>
<td>United States</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Results from the Tukey Comparison

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Lower</th>
<th>Upper</th>
<th>Confidence (MSE =3785.305)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA-Japan</td>
<td>12.928</td>
<td>35.309</td>
<td></td>
</tr>
</tbody>
</table>

Results from the Kruskal-Wallis Rank Test

Prob > ChiSquare: 0.0001

Figure 2.2

Results of the ANOVA model

Dependent Variable: Exchange
Source: Country (Spot, lagged)

<table>
<thead>
<tr>
<th>Source</th>
<th>Pr &gt; F</th>
<th>Pr &lt; W</th>
<th>Normality</th>
<th>Mean-Spot</th>
<th>Mean-Lagged</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot</td>
<td>0.9559</td>
<td></td>
<td></td>
<td>196.7</td>
<td>196.4</td>
<td>0.2878</td>
</tr>
<tr>
<td>Lagged</td>
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<td></td>
<td></td>
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<td></td>
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</table>

Results from the Tukey Comparison

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Lower</th>
<th>Upper</th>
<th>Confidence (MSE =2200.818)</th>
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</thead>
<tbody>
<tr>
<td>Spot-Lagged</td>
<td>-8.2976</td>
<td>8.8731</td>
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</tr>
</tbody>
</table>

Results from the Kruskal-Wallis Rank Test

Prob > ChiSquare: 0.967
Figure 2.3

Results of the ANOVA model

Dependent Variable: Exchange/Predicted Exchange
Source: Type (Spot, Cassel Formula)

| Mean-Spot: 195.727 | Pr < W: 0.0001 |
| Mean-Cassel: 197.244 |
| Difference: 1.517 |

Results from the Tukey Comparison

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Lower</th>
<th>Upper</th>
<th>Confidence (MSE =3170.585)</th>
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</thead>
<tbody>
<tr>
<td>Cassel-Spot</td>
<td>-8.772</td>
<td>11.806</td>
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Results from the Kruskal-Wallis Rank Test

Prob> ChiSquare: 0.5295

Figure 2.4

Results of the ANOVA model

Dependent Variable: Change in Price/Change in Exchange
Source: Country (Percent change in Spot, Percent Change)

| Mean-Ch. Spot: 0.003938 | Pr < W: 0.0001 |
| Mean-Ch. Price Dif.: 0.002677 |
| Difference: 0.001261 |

Results from the Tukey Comparison

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<tr>
<th>Comparison</th>
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<th>Confidence (MSE =.001104)</th>
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<td>0.007369</td>
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Results from the Kruskal-Wallis Rank Test

Prob> ChiSquare: 0.1399
Figure 3.1.1
*Predictions, the last 10 periods*

<table>
<thead>
<tr>
<th>Observation</th>
<th>Price of Yen in Dollars</th>
<th>Expected price</th>
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<tr>
<td>155</td>
<td>0.0074963</td>
<td>0.0076481</td>
</tr>
<tr>
<td>156</td>
<td>0.0074405</td>
<td>0.0073818</td>
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<tr>
<td>157</td>
<td>0.007622</td>
<td>0.0074599</td>
</tr>
<tr>
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<td>0.0075425</td>
</tr>
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<td>0.0075008</td>
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<td>0.0072959</td>
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<td>164</td>
<td>0.0072727</td>
<td>0.0072698</td>
</tr>
</tbody>
</table>

Figure 3.1.2
*A plot of exchange rate vs prices*
Figure 3.1.3
Spot rates and the Cassel formula

Figure 3.1.4
Forecasts for the variable PREDE

The last ten observations:

<table>
<thead>
<tr>
<th>Obs</th>
<th>Forecast</th>
<th>St. Error</th>
<th>Lower Lim.</th>
<th>Upper Lim.</th>
<th>Actual</th>
<th>Resid</th>
</tr>
</thead>
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<tr>
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<td>0.0003</td>
<td>0.0067</td>
<td>0.008</td>
<td>0.0076</td>
<td>0.0003</td>
</tr>
<tr>
<td>156</td>
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<td>0.0005</td>
<td>0.0064</td>
<td>0.0082</td>
<td>0.0074</td>
<td>0.0001</td>
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<tr>
<td>157</td>
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<td>0.0006</td>
<td>0.0061</td>
<td>0.0084</td>
<td>0.0075</td>
<td>0.0002</td>
</tr>
<tr>
<td>158</td>
<td>0.0072</td>
<td>0.0007</td>
<td>0.0059</td>
<td>0.0085</td>
<td>0.0075</td>
<td>0.0003</td>
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<td>0.0072</td>
<td>0.0008</td>
<td>0.0058</td>
<td>0.0086</td>
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<tr>
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Model 3.1.5
Regression Results

Dependent Variable: Erate
Independent Variable: Preda (Cassel variable)
  Intercept: 0.000135
  Coefficient: 0.975861
  Prob> T   0.0001
  R-Square:  0.9606
Model 3.1.7
Regression Results

Dependent Variable: Erate
Independent Variable: Lagerate (a lag of one)
  Intercept: 0.0001
  Coefficient: 0.9845
  Prob> T 0.0001
  R-Square: 0.9641

Figure 3.2.1
The Arima procedure

Maximum Likelihood Estimation
Parameter Estimate St. Er. (ap T-Ratio) Lag
  MU: 0.005256 0.000398 13.21 0
AR 1,1: 0.65619 0.07469 8.79 1
AR 1,2: 0.29705 0.07484 3.97 2

Autocorrelation Check for Residuals
To Lag Chi Sq Prob
  6 1.01 0.909
  12 8.55 0.575
  18 12.57 0.704
  24 21.22 0.507
  30 26.21 0.561

Model: 1-0.65619 B**(1) - .29705 B**(2)
Figure 3.2.2
Forecast for variable REALERAT

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<th>Upper 95</th>
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Figure 3.3.1
Results of Restricted

ADJFTST1: 0.044038
ADJFTST2: 0.091429
ADJFTST3: 0.03996
ADJFTST4: 0.035447
ADJFTST5: 0.078184
Figure 3.4.1
Productivity Levels, 1978-1990

Figure 3.4.2
Percent Changes in Productivity
Figure 3.4.3

Japanese Productivity Gain, 1978-'90

Figure 3.4.4

Regression Results

Dependent Variable: WPIJapan
Independent Variable: Productivity, Japan
  Intercept: 101.02
  Coefficient: -0.0753
  Prob > T: 0.0451
  R-Square: 0.0185
Figure 3.4.5
Regression Results

Dependent Variable
Independent Variable
Intercept: 14.188
Coefficient: 0.8406
Prob > T: 0.0001
R-Square: 0.549

Figure 3.4.6
Regression Results

Dependent Variable
Independent Variable
Intercept: 761.97
Coefficient: -567.18
Prob > T: 0.0001
R-Square: 0.3392
References


David, Paul A. "Just How Misleading are Official Exchange Rate Conversions?" in Economic Journal, Volume 83 (December, 1983).


Dueker, Michael J. "Hypothesis Testing with Near-Unit Roots: The Case of Long-Run Purchasing Power Parity," in papers of the Federal Reserve Bank of St. Louis, (July/August, 1993).


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