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Purchasing Power Parity and Frequency Domain Filtering.

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ABSTRACT

Purchasing Power Parity (PPP) theory is one of the most enduring concepts in economics. The theory establishes a long-run relationship between prices and the nominal exchange rate. The important contribution of this paper stems from the application of a new and original econometric methodology as well as the unusually long data series. In this paper, PPP is reexamined using the Christiano and Fitzgerald filter, applied to over a century of data for 10 countries. The countries in question are Canada, Denmark, Finland, Italy, Norway, Portugal, Sweden, Switzerland and the United Kingdom, all tested against the United States. Using the above technique, strong evidence of PPP is uncovered while more traditional techniques continue to be unable to find support. The application of the Christiano and Fitzgerald filter provides a new and exciting direction for further research on PPP.

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It is good to have an end to journey toward;
but it is the journey that matters, in the end.

Ursula K. Le Guin

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Chapter I – INTRODUCTION

Few would dispute that the most notorious advocate of the theory of Purchasing Power Parity was a Swedish economist named Gustav Cassel. In 1918, Cassel defined and formally named PPP in the "Economic Journal". Though not credited as the original creator of PPP, Cassel championed the mathematical and empirical applications of the concept. In the words of Cassel, "As long as anything like free movement of merchandise and a somewhat comprehensive trade between two countries takes place, the actual rate of exchange cannot deviate very much from this purchasing power parity".[1] Thus, very simply stated, arbitrage between different countries will equate prices for identical commodities in the long run. In Cassel's early work, he proposed that PPP was a theory of exchange rate determination. If a PPP relationship does hold between two countries, then not only is the PPP rate of exchange a reliable predictor of future exchange rates but more importantly, an accurate one. Understandably, there has been some doubt as to the validity of PPP as an accurate predictor of future exchange rates. This aspect of PPP has never received much supported empirically and Cassel himself revised his opinion in later work.

While the doctrine of PPP is fundamental to international economics, it is of some interest to develop an understanding of some of the limitations faced by PPP as a predictor of exchange rates.

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[1] Gustav Cassel, "Abnormal Deviations in International Exchanges" Economic Journal 26, 1918 p 413

As one of the foundations for price and exchange rate behavior in an open economy, PPP is entrenched with price behavior and all of the limitations faced by statisticians when calculating price indices, like the consumer and wholesale price index. Obviously the 'basket' of goods used, by both countries, to estimate a price index cannot differ in order for effective comparison, and yet they probably do. Some other weaknesses of price indices include differing base years and weights used by each country as well as the fact that some services are not tradable in the international market.

Impediments to international trade, like quotas, import duties, transportation costs, insurance costs, storage costs etc, as well as information costs in the process of arbitrage, all affect the level to which arbitrage can erode away price differentials. Thus such external costs weaken the extent to which PPP can predict future exchange rates. Note however, that while the presence of such external costs hinders prices between countries from equalizing, it does not necessarily mean the market is inefficient, but rather the price differential, at least, must equal the transaction costs.

It is important to remember that international movements of capital influence exchange rates. Therefore structural changes that may cause such movements, for example an announcement of a change in monetary policy, will have an effect on the ability of PPP to predict exchange rates, since exchange rates react to such structural changes independently of relative prices.

Finally, to predict future exchange rates with PPP, we need a measure of expected future prices (or equivalently, expected inflation). These expected prices are subject to statistical errors (due to imperfect foresight) and are most likely going to differ from actual prices. This again would weaken PPP's ability to predict future exchange rates.

All of these factors weaken the theory of PPP in terms of its ability to efficiently estimate exchange rates. Based on this conclusion of poor proficiency, combined with its critical role in international economics, economists have worked tirelessly to empirically uncover if PPP does in fact hold. An in-depth literature review is presented in the next chapter, which summarizes recent attempts by economists to derive results that are consistent with PPP. However, it is worthwhile to characterize the past plethora of literature into a few major categories to clearly identify where the emphasis of work has been and where there is room for exploration.

With such an abundance of literature on the topic of Purchasing Power Parity, it often seems that many of the papers may create as much confusion as they do clarity on the topic. There has been a long progression of work done and the major developments will be briefly discussed here. There are three identifiable stages in the literature. The firsts attempts at empirically proving PPP were centered on PPP as the null hypothesis. Throughout the 1970's the emphasis was on the importance of temporary disturbances to PPP. However, early formal empirical analyses were limited by the absence of statistical and theoretical tools distinguishing between short run and long run real effects. In fact, outside hyperinflations most of the early tests produced strong rejections of PPP. A

fundamental flaw in the econometrics of these early tests is the failure to take explicitly into account the possible nonstationarity of relative prices and exchange rate. Today it is well known that if there is a unit root in the error term then standard hypothesis tests are invalid. The key lesson derived from the initial tests of PPP was that PPP does not hold continuously, but the results provided no perspective on whether PPP might be valid as a long-run proposition.

Based on these disappointing results and flawed hypothesis testing, econometricians tried a new approach. In the next stage of testing, the null hypothesis was the real exchange rate follows a random walk, with the alternative hypothesis being that PPP holds in the long run. The main problem with this branch of testing was low power. Much of the evolution to this stage of testing has revolved around finding longer or broader data sets and finding more powerful unit root tests. There are three main econometric techniques used to test for stationarity, Dickey Fuller and Adjusted Dickey Fuller tests, variance ratios and fractional integration. The basic result for all three techniques is that it is difficult to reject the null hypothesis, implying PPP does not hold.

The final major stage in the empirical work related to PPP was the cointegration movement. Engle and Granger's (1987) cointegration test primarily inspired this body of work. The main advantage of the cointegration test is that it offers the promise of testing weaker versions of PPP, since it requires that only some linear combination of exchange rates and prices be stationarity. Early applications of cointegration methods to test PPP were based on a three-step procedure. The first step involved testing the exchange rate

and both price series for a unit root, typically with the Adjusted Dickey Fuller test. For the bivariate case, of course, there are only two series, the exchange rate and relative prices. Assuming that one cannot reject the random walk hypothesis for any of the variables, the second step is to estimate the cointegrating regression using OLS. Cointegration of prices and exchange rates implies that the error term is stationary. Thus the third step is to use the OLS residuals and test them for stationarity. Using this approach, prices and exchange rates are not cointegrated under the null hypothesis while they are cointegrated under the alternative hypothesis.

Unfortunately, this three-step method is inherently inefficient because it requires choosing, rather arbitrarily, a single right-hand side variable. More recent PPP tests have been able to avoid this inefficiency, using a technique introduced by Johansen. Johansen introduced a one-step, full information maximum likelihood estimator for estimating the coefficients and simultaneously testing for the presence of a unit root. Unlike the method above, the ML estimates are not influenced by which variable is on the left-hand side of the single equation regression. The parameter estimates are thus more efficient, and the Johansen test for cointegration is more powerful than the three-step test.

There has been a surplus of papers applying cointegration testing to PPP, but on the whole it is not clear that the technique has yet provided a net benefit over earlier tests, indeed it may have produced some misleading results due to small sample bias. Over longer time periods and for fixed rates, the bias becomes less serious. Thus far, however,

the results from cointegration tests on long-horizon data have not produced any substantial insights from those of previous tests.

With so much work done on the topic of PPP and the tendency towards rejecting the PPP hypothesis, it seems important to adequately justify why another attempt deserves any attention. Despite the numerous publications and their corresponding empirical contributions, PPP has never ceased to be a topic of interest. However, it is time to consciously consider the work that has been done previously and stop repeating techniques that have been unsuccessful. The emphasis should no longer be on revising those traditional techniques such as Adjusted Dickey Fuller and Engle Granger. These techniques should only be utilized if some substantial new variation will be presented, making the contribution worthwhile. As such, it is necessary to provide evidence that suggests *this* paper does in fact make a valuable contribution to the ever-growing body of literature surrounding PPP. This is accomplished in two distinct ways. The first major contribution of *this* paper comes from the data itself. One repeated recommendation from econometricians, regardless of the econometric technique used, is to use a long data series. Because Purchasing Power Parity is a long run proposition, it is critical to the success of the testing, to use a long time span for the exchange rate and price series. Unfortunately, the data necessary to test PPP is typically available only for a few decades, which is insufficient. What makes this paper distinctive is that the data series tested for each country span well over a century. Few papers have used such a long series and hence this paper is making a significant contribution.

The next major factor that differentiates this paper from others is the new and advanced econometric technique that does not resemble anything that has been done in the past. The Christiano and Fitzgerald filter is an innovative and rather econometric technique, which introduces an entirely new branch of testing to be applied to PPP. It does not fall into any of the three major branches of testing discussed above and thus represents an original effort. New and advanced econometric techniques are necessary to breath new life into the topic of PPP, since it is inevitable that the current state of the literature is stagnating. Since the topic of PPP is critical to international economics, there is no room for such stagnation, until the theory has a reasonable amount of empirical support behind it.

This paper will follow the following format. Chapter II will outline the theory of PPP in detail. The three facets of PPP, the law of one price, absolute PPP and relative PPP will be discussed. As well, the testing methodologies traditionally used, namely looking for a cointegrated relationship between the exchange rate and prices and testing for stationarity of the real exchange rate will be presented. A detailed literature review follows, presenting the most recent and relevant articles pertaining to PPP. The literature review is divided into two subsections corresponding with the popular testing methodologies, one section covers work done on testing for a cointegrating relationship while the subsequent section covers work done on testing the stationarity of the real exchange rate.

Chapter III introduces the data to be used and filtering as a means of testing for PPP. The data specifications, sources and other relevant information pertaining to the data series are discussed. Next, we specifically consider the Christiano and Fitzgerald filter and show the mathematical derivation. For completeness, the Christiano and Fitzgerald filter is compared to past popular filters. Having done that we are in a position to perform the actual empirical work. Not only is the Christiano and Fitzgerald filter applied but Monte Carlo estimation is also preformed. The procedures to test for PPP are discussed in detail and two means of evaluation are introduced. All results for each country are presented and the two methods of evaluation are compared. Conclusions are then drawn from these results. The final chapter, Chapter IV, presents a synopsis and the policy implications. After endeavoring on such a lengthy passage, the reader is best served by a concise review of what the objective was at the onset. In this section, the goal is to leave a lasting impression and potential areas for further research. Most importantly in this section we want to explore the possible policy implications. Academic papers are not only written for the purpose of furthering economics as a science but also for the more practical purpose of having a real world application. As such, it is worthwhile to consider how monetary policy makers and the government could use the theory of PPP.

Chapter II – THEORY & LITERATURE REVIEW

1. INTRODUCTION

The theory of Purchasing Power Parity is a core assumption in exchange rate models in international economics. In the case of fixed exchange rates, PPP explains why the domestic inflation rate must equal the foreign inflation rate and under a floating exchange rate regime provides a theory of exchange rate determination. The latter case is the most interesting today as PPP provides a benchmark for policy makers and exchange traders.

Purchasing Power Parity provides a long run relationship between the exchange and prices in an open economy. Technically therefore, it provides an equilibrium value towards which the underlying currencies will converge, and hence PPP has some practical appeal for exchange rate determination. However, the Purchasing Power Parity relationship is weak in the short run and is typically not believed to hold in the short run by economists.

2. PPP, A THEORETICAL BACKGROUND

Modern economics now embraces three variations of the concept of PPP: *the law of one price, absolute PPP and relative PPP.* In the next sections, we consider each of these three concepts in detail.

2.2. THE LAW OF ONE PRICE:

The law of one price holds that identical goods in different countries should have the *same price* once denominated in the *same currency*. This concept holds only if external costs such as transportation costs or tariffs can be ignored and the goods in question are homogeneous i.e. perfect substitutes. The success of the law of one price depends on arbitrage between countries. If prices for identical goods differed and external costs were negligible then the potential for arbitrage would exist. This arbitrage would eliminate any price differential between the goods. Through the laws of supply and demand relative to price, the price differential would dissipate over time. More specifically, an excess demand for the lower priced good would increase its price, and an excess supply of the good in the country where the price is higher would eventually cause the price to fall, until the prices in both countries equate and there is no longer any potential for arbitrage. The process of equating prices is time consuming and explains why PPP is favored more as a long run relationship instead of a short run relationship. A mathematical representation of the law of one price is given through the equation:

(1) $$S = A\frac{P}{P^*}$$

where S is the nominal spot exchange rate, P and P* are the prices for an identical commodity in the domestic and foreign country respectively and A is an arbitrary constant. This equation suggests that the nominal exchange rate can be expressed as the ratio of two nominal variables.

2.3. ABSOLUTE PURCHASING POWER PARITY:

The fundamental difference between the law of one price and absolute PPP is that absolute PPP uses general price levels in the economy rather than one specific commodity's price. Thus the definition of PPP can be slightly modified here to state that the general prices in two economies will converge over time once converted to the same currency. In empirical work, price indices are generally used to represent general price levels. For example the Consumer Price Index (CPI), which is a weighted average of a basket of goods, is commonly used. However, this representation of price levels has inherent measurement problems. For example, the basket of good used will probably not contain identical goods and the weight used to calculate the price index are not the same. Despite its inherent flaws, the CPI remains an adequate variable in calculating PPP.

The mathematical equation for absolute PPP can be written as follows:

(2) $$S = A\frac{CPI}{CPI^*}$$

Again S is the nominal spot exchange rate, A is an arbitrary constant and CPI and CPI* represents the price indices for the domestic and foreign country respectively.

If the price index used is the CPI for each country, it is worthwhile to consider the relationship between the *law of one price* and *absolute Purchasing Power Parity*. The Consumer Price Index (CPI) is a measure of the average change in prices over time in a market basket of goods and services. In other words, the prices of everyday goods such as housing, food, education, clothing, etc. are compared from one month to the next and the difference represents the CPI. Of course the goods are weighted appropriately in order to get an accurate measure. If the law of one price holds and the weights used to calculate CPI and CPI*, where CPI* is the foreign country's consumer price index, are the same, then absolute PPP holds as well. If however, the weights are not the same, then we require another restriction. In particular, if one good's price changes, the contribution of this change to the CPI has to be offset by an opposite change in the price of some other good with not necessarily the same weight. Under such a circumstance, absolute PPP may still hold even if the law of one price does not. In other words, even if individual prices in an economy are not the same, general prices in the economy may be equal. Hence, absolute PPP is believed to be a superior concept than the law of one price.

2.4. RELATIVE PURCHASING POWER PARITY:

Similar to absolute PPP, relative PPP looks at the relationship between exchange rates and prices in terms of growth rates. Thus, the relative Purchasing Power Parity

relationship is between exchange rates and inflation rates. In other words, one country's exchange rate can only be higher than another countries to the extent that the exchange rate depreciates. To see this mathematically, we begin by taking the natural logarithm of both the exchange rate and the price indices.

(3) $$\ln S = \ln A \ln \frac{CPI}{CPI^*} \quad = \alpha + \ln \text{CPI} - \ln \text{CP1}^*$$

Let s = ln S, cpi = ln CPI and cpi* = ln CPI* and $\alpha = \ln A$. This version of PPP states that A=1, or equivalently that (3) holds with the aditional restriction that $\alpha = 0$. Rewriting the above equation in terms of growth rates we get:

(3a) $$\Delta \ln S = \Delta \ln CPI - \Delta \ln CPI^*$$
$$\Delta s = \Delta cpi - \Delta cpi^*$$
$$\Delta s = \pi - \pi^*$$

where π and π^* are the domestic and foreign inflation rates respectively and $\Delta s = s_t - s_{t-1}$.

Comparatively, some economists feel that relative PPP is a improvement over absolute PPP because by being in terms of growth rates it eliminates the need to choose a base year as well as accounts for external costs. It is also valuable to note that if absolute PPP holds, then relative PPP clearly holds as well. However, if absolute PPP fails to

hold, relative PPP may still hold i.e. even if the exchange rate is not equal to the exact ratio of the price indices, it may at least be comparable to it.

3. TEST METHODS

The above summarizes the theoretical foundations behind purchasing power parity. Now we can examine the key tests typically used to test for long run purchasing power parity. An examination of the existing literature reveals that there are two prevalent testing procedures. In general, absolute PPP, as defined by equation (3) above is tested by estimating the regression

$$\ln s_t = \alpha + \beta \ln CPI_t - \beta^* \ln CPI_t^* + u_t \tag{4}$$

and testing the null hypothesis that the coefficients of the logs of domestic and foreign prices are equal to unity, as implied by equation (3), i.e. $\beta = \beta^* = 1$. Alternatively, we can regress the nominal exchange rate on the relative price and estimate the equation

$$\ln s_t = \alpha + \beta \ln(CPI_t / CPI_t^*) + u_t \tag{5}$$

and then test PPP by testing the hypothesis that $\beta = 1$.

Such tests, however, are based on the assumption that u_t is white noise. If (in the context of equation (5)) $\ln s_t$ and $\ln(CPI_t / CPI_t^*)$ are each integrated of order one, or are I(1), then it is typically true that a linear combination of these variables will also be I(1). However if a linear combination of these variables is integrated of order zero, or I(0), then $\ln s_t$ and $\ln(CPI_t / CPI_t^*)$ are said to be cointegrated. This cointegrated relationship is essential for PPP to hold once the relevant variables stationarity properties are known. This procedure of testing cointegration is one of the foremost methodologies to test for the existence of PPP and will be discussed further in the next section.

The other important testing methodology involves testing for stationarity of the real exchange rate. The real exchange rate by definition, is the price of foreign goods and services relative to domestic goods and services and is measured as followed

(6) $$E = S \cdot \frac{P}{P^*}$$

where E is the real exchange rate, S is now the foreign price of one unit of domestic currency, and the other variables are as in equation (2). The motivation and desired outcome for testing the stationarity of the real exchange rate will be discussed in the next section in more detail.

3.1. STATIONARITY AND COINTEGRATION

The first major technique to test for the existence of purchasing power parity is to test for a cointegrated relationship between prices and the exchange rate. For purchasing power to exist, empirical work should be able to reveal a cointegrated relationship between prices and the exchange rate. In order to uncover this relationship, the stationarity properties of the variables must first be examined. The variables must be integrated of the same order, namely integrated of order one; I(1), to be able to proceed with cointegration tests. If the variables in question are I(1), then it is possible that a linear combination of the variables may share a long run relationship, hence they are cointegrated. Some of the more traditional cointegration tests applied are the Engle-Granger univariate test and Johansen's multivariate technique. In section 4, we consider the actual literature that applies the testing procedures discussed above in the hopes on discovering the existence of purchasing power parity.

Setting up the model, we begin with a simple random walk model

$$X_t = X_{t-1} + \varepsilon_t \tag{7}$$

where X_t is a time series and $\varepsilon_t \sim N(0,\sigma^2)$.

If we consider the first log difference version of the model then such a series has both mean and variance that are constant and finite since ε_t is normally distributed with mean 0 and variance σ^2. Such a series would then be integrated of order 1, I(1).

Expanding this model, we get the non-augmented Dickey Fuller regressions:

(8) $$X_t = \alpha X_{t-1} + \varepsilon_t$$

(9) $$X_t = \theta + \alpha X_{t-1} + \varepsilon_t$$

(10) $$X_t = \theta + \beta(t - \frac{T}{2}) + \alpha X_{t-1} + \varepsilon_t$$

where equation (8) has neither drift nor trend, equation (9) has drift but no trend and equation (10) has both drift and trend. Drift is the intercept while the linear trend may be deterministic or stochastic. The fundamental difference between the two is that the former is such that the time series is mean-reverting while the latter will have no such inherent tendency. Here T is the sample size. The null hypothesis is: $H_o : \alpha = 1$, if the null hypothesis is rejected, the series is said to be stationary or integrated of order 0, I(0).

The above section attempts to shed light on the importance of testing for unit roots in time series, as well as the most common test statistic that is used, the ADF test. We can now move on to consider cointegration in more detail.

There are a number of methodologies to that can be used to test for cointegration. One of the most popular techniques applied in the literature is the Engle Granger test. The Engle Granger test requires that three conditions hold.

i) All elements of X_t are non-stationary in levels,

ii) Stationary in first differences and

iii) Be linearly combined to form a variable Z_t, such that Z_t is stationary in levels.

The third condition requires that Z_t, or the real exchange rate, is integrated of order zero, I(0). This implies that if Z_t has zero mean it will rarely drift far from zero and will often cross the zero line i.e. an equilibrium is often found. If all of these conditions hold then X_t is said to be cointegrated, however if any of these conditions fails to hold then X_t is not cointegrated, implying that Z_t will tend to wander widely which would make a zero crossing and hence an equilibrium almost impossible to achieve.

3.2. STATIONARITY OF THE REAL EXCHANGE RATE

The other testing procedure involves testing for stationarity of the real exchange rate. Recall that the real exchange rate, by definition, is the price of foreign goods and

services relative to domestic goods and services. The real exchange rate is measured as follows

$$(11) \qquad E = S \cdot \frac{CPI}{CPI^*}$$

where E is the real exchange rate, S is the foreign price of one unit of domestic currency and CPI and CPI* are the domestic and foreign price indices respectively. The real exchange rate is important because it measures short-run deviations from PPP and if it follows a random walk then PPP does not holds. The null hypothesis is that the real exchange rate is a random walk, in other words the null hypothesis is that PPP does not hold. For purchasing power parity to exist, the real exchange rate must be I(0) and shocks to the variable must dissipate over time. If the real exchange rate does not contain a unit root, in other words, the variable is integrated of order zero, I(0), then purchasing power parity exists. As such, a significant amount of literature is concentrated in the area of stationarity testing of the real exchange rate. The data used for these tests is arranged either as time series or panel data. The types of tests used vary widely among the literature though there is an abundance of traditional stationarity test such as the Adjusted Dickey Fuller and Phillip Perron tests.

Both of the above techniques, looking for cointegration and testing the real exchange rate, are used abundantly in the literature. In the next section, we consider some of the papers that actually apply these techniques to different data series.

4. LITERATURE REVIEW

The question of the existence of Purchasing Power Parity has been studied extensively and the empirical results remain mixed. However, by using different sample sizes, frequency of observations, countries studied and contingent on the empirical test used, some authors have reported empirical results in favor of long run PPP. Interestingly, as econometric techniques become more advanced, more authors are reporting empirical evidence supporting the existence of PPP.

Due to the abundance of empirical work done in the area of PPP, it would be a formidable task to accurately summarize all of the work done to date and thus such a task is not attempted here. What follows is a select and concise review of relevant journals with a strict concentration on work done in the recent past (1997 to present). A final section will attempt to draw some conclusions about the success/failures of the research to date and identify areas where more research should be focused.

Recall that there are two fundamental tests of PPP. The first is to test the stationarity of the real exchange rate and the second is to examine the relationship between the price level/inflation rate and the exchange rate. Due to the abundance of literature and rapidly advancing econometrics techniques, we will organize the available literature into two sections based on the test of PPP used. We begin with the authors who tested the real exchange rate for stationarity. The next section will summarize works done

by those authors investigating the existence of a cointegrated relationship between the necessary variables.

4.1. TESTING THE REAL EXCHANGE RATE

The most common stationarity test used to test the real exchange rate is the Adjusted Dickey Fuller Test (ADF). Wu (1997) used ADF, as well as the Phillips Perron (PP) and the Zivot and Andrews test to examine the stationarity properties of 11 OECD countries from 1979-1994, with a base currency of the U.S. dollar, using monthly data. Zivot and Andrews have developed methods to endogenously search for a break point and test for the presence of a unit root when the process has a broken trend. With ADF and PP, no support was found in favor of long run PPP; however, using Zivot and Andrews the null hypothesis of a unit root in the real exchange rate can be rejected for the majority of OECD countries.[2]

Similarly, Guimaraes-Filho (1999) tested the real exchange rate using both ADF and PP tests as well as the KPSS test for Brazil and the U.S., for the period 1855-1990 using the dollar as the base with annual data. Both the ADF and the PP test have null hypotheses of a unit root in the series. Another widely used unit root test proposed by Kwiatkowski et al., the KPSS test, has a null hypothesis that the series is stationary against the alternative hypothesis of a unit root. Consistent with above, he was not able to find any support for long run PPP. Following a large literature of 'rank tests', Hasan and

[2] Yangru Wu. "The Trend Behavior Of Real Exchange Rates: Evidence from OECD Countries." Weltwirtschaftliches Archive, 1977. Vol. 133(2). P293

Koenker propose a new test procedure of the unit root hypothesis. The Hasan and Koenker test, which the author believes to be robust, was used but again no support was found.[3]

Two more authors, Bahmani-Oskooee and Mirzai (2000), tested the stationarity properties of the real exchange rate using ADF and KPSS for 19 developed and 22 developing countries, for the period 1973-1993, using quarterly data. The ADF test did not support stationarity of the real effective exchange rate (and thus PPP) in the majority of developing countries, the KPSS test did.[4]

Using ADF, along with the Dickey Fuller Generalized Least Squares (DFGLS), and four other stationarity tests, Kuo and Mikkola (1999) present evidence that the real exchange rate is stationary for an annual series from 1859-1992 for the U.S. and U.K. This conclusion holds for tests with a null of unit root as well as for tests with a null of stationarity.[5] The DFGLS is a modified version of the ADF test that has improved power. The modifications are with respect to the method of estimating the deterministic term and the power is increased without otherwise altering the method of testing.

Using ADF, DFGLS as well as fractional and structural break analysis, Cheung and Lai (2000) provide an extensive cross-country analysis of PPP reversion, using the

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[3] Roberto Fernandes Guimaraes-Filho. "Does Purchasing Power Parity Hold After All? Evidence from a Robust Test." Applied Financial Economics, 1999. Vol. 9. p171

[4] Mohsen Bahmani-Oskooee, Aghdas Mirzai. "Real and Nominal Effective Exchange Rates for Developing Countries: 1973:1-1997:3" Applied Economics, 2000. Vol.32 p428

[5] Biing-Shen Kuo, Anne Mikkola. "Re-examining Long-run Purchasing Power Parity." Journal Of International Money and Finance, 1999. Vol. 18 p264

data on dollar based real exchange rates for 94 countries. Fractional integrated processes can display mean reversions, not captured by traditional stationary processes. To account for possible structural shifts sequential unit root tests devised by Banerjee et al. are performed. The analysis uncovers significant heterogeneity in the behavior of real exchange rates across countries or groups of countries. Various forms of parity reverting dynamics are detected and substantial variations in the persistence of PPP deviations are also observed. The results also show that there is an increased probability of finding parity reversion for developing countries compared to industrial countries.[6]

Bleaney et al. (1999) examine mean reversion in real exchange rates using data for five countries, four of which have experienced episodes of high inflation. Using a monthly sample spanning 1972:1-1993:5 and wholesale prices, the ADF and LeybourneMcCabe (LM) test are used as well as a Kalman filter. The LeybourneMcCabe stationarity test takes stationarity as the null and has a unit root alternative. The Kalman filter is used to estimate the root trajectories through time. Simple (ADF) tests of mean reversion and the LM test reject stationarity of the real exchange rate. The Kalman filter estimates of the stochastic unit root show sharp deviations from unity associated with high inflation episodes. The conclusion reached by the authors is that mean reversion in exchange rates is strongly influenced by high inflation and has characteristic spikes corresponding to these episodes. This suggests that stochastic unit root models are a more appropriate way to model mean reversion in real

[6] Yin-Wong Cheung, Kon S. Lai. "On Cross-country Differences in the Persistence of Real Exchange Rates" Journal of International Economics, 2000/ Vol. 50 p394

exchange rates for high inflation countries than models with fixed rates of mean reversion.[7]

Another popular technique to test the stationarity of the real exchange rate is using panel data. Meier (1997) used Generalized Least Squares (GLS) and Seemingly Unrelated Regression (SURE) versions of the Dickey Fuller test for 10 OECD countries for the period 1979-1994, with a base of the U.S. dollar, using annual data. The least restrictive way to exploit the panel-type structure of real exchange rate data from different currency pairs is to estimate the Dickey-Fuller autoregressions as a system of seemingly unrelated regressions (SURE). The procedure allows both the intercept and the autoregression coefficient to vary across the individual real exchange rate equations. As long as the disturbances of the equations are correlated to some extent, the GLS estimator, which takes these cross-equation correlations into account, will be more efficient than equation-by-equation OLS. For this study the author did not use the Consumer Price Index (CPI) but instead used 'value added deflators for manufacturing'. The results generated provide evidence of long run PPP for European countries. For the U.K., Japan and Canada the system is re-estimated under the restriction that the auto regressive coefficients are equal across equations and support for PPP is again generated.[8]

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[7] Michael F. Bleaney, Stephen J. Leybourne, Paul Mizen. "Mean Reversion of Real Exchange Rates in High Inflation Countires." Southern Economic Journal, Apr. 1999 Vol.65 p839

[8] Carsten-Patrick Meier. "Assessing Convergence to Purchasing Power Parity: A Panel Study for Ten OECD Countries" Weltwirtschaftliches Archiv, 1997. Vol.133(2)

Ankler (1999) again used panel data (quarterly) for the period 1973-1997 for 18 industrialized countries with a base of the dollar as well as the Deutsche Mark (DM). To create real exchange rates, the CPI and the Wholesale Price Index (WPI) were both used. Using GLS, evidence for long run PPP could be generated with the DM and the CPI and even stronger evidence when the WPI is used. Weaker results were generated for the CPI with the dollar.[9] When proper account is taken of the cross-sectional and serial correlation properties in the estimation and simulation and serial correlation properties in the estimation of rebasing from the German mark to the dollar in panels using information from the same countries. In other words, there are no significant gains from using the Deutsche Mark versus the dollar. This conclusion will be explored further in a future section.

Another panel unit root test is the Im, Pesaran and Shin (IPS) test, which was used by Boyd and Smith (1999) on 31 developing countries with the dollar as the base for the period 1966-1990, using annual data. Monte Carlo evidence suggests that the IPS test, which is based on the average ADF statistic, has more power that comparable panel unit root tests. These authors compare tests of the real exchange rate using both time series and panel data. Their results show that there exists more evidence in favor of long run PPP when panel data is used.[10]

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[9] Peter Anker. "Pitfalls in Panel Tests of Purchasing Power Parity" " Weltwirtschaftliches Archiv, 1999. Vol.135(3)

[10] Derick Boyd, Ron Smith. "Testing for Purchasing Power Parity: Econometric Issues and an Application to Developing Countries" The Manchester School. Vol.67 No.3 June, 1999. p 302

One particular paper by Alan Taylor is perhaps the most interrelated and deserves special attention. The reason for the unique relationship is that Taylor used the same data set as used in this paper. More specifically, Taylor fashioned the extraordinarily long data set of 20 countries, from which a smaller subsection of 10 countries was donated for this paper. While the two papers are similar in terms of the data used, that is where the similarities stop. Taylor created a panel of data and was interested in testing the stationarity of the real exchange rate. Taylor's data consists of 20 countries spanning 1892 to 1996 using the U.S. dollar as the base currency. A traditional stationarity test was applied, the Dickey Fuller test, which yielded the typical result of not rejecting the null of a unit root for most countries. More advanced techniques are subsequently applied, both multivariate and univariate. The multivariate test applied was the Johansen Likelihood Ratio test while the univariate tests used were the Elliot, Rothenberg and Stock (ERS) test and the DF GLS test. The results are consistent with long run PPP using these recent multivariate and univariate tests of higher power.[11] With some allowances for the possibility of slow evolving long run trends, Taylor concludes that PPP has held in the long run over the twentieth century for the sample of 20 countries.

Using a multivariate framework, which asks whether any linear combination of prices and exchange rates are stationary, to test the real exchange rate, Flores et al. (1999), use monthly data from 1973-1994 for G10 countries plus Switzerland with the dollar and DM as the base. The authors do not impose a common speed of mean reversion thus allowing for different mean reversion parameters. The speed of mean reversion can be categorized by the half-life of a shock. As Froot and Rogoff (1995) note

[11] Alan M. Taylor, "A Century of Purchasing Power Parity" NBER Working Paper Series #8012, 2000, p2

in their review article, "consensus estimates put the half-life of deviations from PPP at about 4 years for exchange rates for industrialized countries." However, there are also econometric reasons to allow for different speeds of mean reversion. The authors show that allowing for different speeds of mean reversion improves the test results and provides additional insights into the different behavior of real exchange rates. The results show six countries have a stationary real exchange rate using the dollar while weaker results are generated for the DM. Thus they conclude the PPP exists for European countries although they have different speeds of mean reversion.[12] The weaker results using the DM slightly contrast the previously discussed paper by Ankler (1999), which had stronger evidence with the DM.

Maeso-Fernandez (1998) tested the real exchange rate for 19 countries using monthly (1974-1994) and annual (1948-1994) data with the dollar as base. Using the CPI and WPI, a variance ratio test is used. The variance ratio test has as the null hypothesis that the permanent component of a time series is more important than the transitory one. The test can be seen as a traditional unit root test for a fixed lag. The variance ratio test shows that the hypothesis of explosive behavior of the real exchange rate is rejected in most cases. The results are more favorable when annual data and wholesale prices are used.[13]

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[12] Renato Flores, Philippe Jorion, Pierre-Yves Preumont, Arian Szafarz. "Multivariate Unit Root test of the PPP Hypothesis" Journal of Empirical Finance, 1999. Vol.6 p350

[13] Francisco Maeso-Fernandez. "Econometric Methods and Purchasing Power Parity: Short and Long-run PPP." Applied Economics, 1998. Vol. 30 p1455

Using panel data methods, Papell (1997) investigated long run PPP by testing for unit roots in real exchange rates of industrial countries under the current float. Using 20 countries with quarterly observations and 17 countries with monthly observations, the GLS test was applied on the entire sample as well as sub samples. The sub samples tested were the G6 countries, European Community (EC) and European Monetary System (EMS). The evidence against the null hypothesis of a unit root is stronger for larger rather than smaller panels, for monthly rather than quarterly data and when the German mark rather than the U.S. dollar is used as the base currency.[14]

O'Connell (1998) believes that real exchange rates are cross-sectionally dependant and recent panel studies of PPP fail to control for cross-sectional dependence in the data. The variables are dependant because by construction they contain common components, namely independent variation in the value of the dollar and independent variation in the U.S. price index. Using quarterly data from 1973:2-1995:4, the real exchange rate was tested for 64 countries using the member country price series rather than U.S. price index. The entire sample was used as well as sub samples of Europe (20 countries), Asia (13 countries), South America (13 countries) and Africa (13 countries) and test using GLS/FGLS allowing for serial correlation and contemporaneous serial correlation. It is shown in the paper that, controlling for cross-sectional dependence, no evidence against a random walk null can be found in panels of up to 64 real exchange

[14] David H. Papell. "Searching for Stationarity: Purchasing Power Parity under the Current Float." Journal of International Economics, 1997. Vol. 43. p330

rates. The author asserts that this finding cannot be attributed to low power, as there is ample power in panels of this size to reject the unit-root null.[15]

The above section provides a concise overview of journals testing the existence of PPP by testing the real exchange rate, either using univariate time series or multivariate panel data techniques. The next section will now focus on those papers whose methodology was to test for cointegration among the relevant variables. Recall that to properly test for cointegration among variables, the stationarity properties of each variable must first be determined to insure all variables are integrated of the same order.

4.2. TESTING COINTEGRATION OF VARIABLES

One of the most common methodologies used to test for PPP is to apply one of many stationarity tests, such as ADF, PP, KPSS, etc., followed by either the Engle-Granger (EG) or Johansen tests of cointegration. Culver and Papell (1999) used ADF and Engle-Granger to test for cointegration on quarterly data for 21 industrialized countries using the dollar as the base for the period 1973-1996. These authors also used the KPSS test for stationarity and the Shin version of the KPSS test for cointegration. Using ADF with EG, the authors find little or no evidence consistent with long run PPP. Using KPSS and the Shin version of KPSS some support is found for long run PPP.[16]

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[15] Paul G. J. O'Connell. "The Overvaluation of Purchasing Power Parity." Journal of International Economics, 1998. Vol.44 p1

[16] Sarah E. Culver, David H. Papell. "Long-Run Purchasing Power Parity with Short Run Data: Evidence with a Null Hypothesis of Stationarity" Journal of International Money and Finance, 1999. Vol.18 p766

Again using ADF for stationarity, along with EG and Johansen for cointegration, Doganlar (1999) tests for PPP among five developing Asian countries using quarterly data for the period 1980-1995 with the dollar as base. Little or no support could be generated for long run PPP for this series.[17]

Three additional papers use ADF with Johansen in an attempt to find empirical support for PPP. Salehizadeh and Taylor use monthly data for the period 1975-1997 for 27 countries with the dollar as the base. In this paper the authors pay special attention to the restriction on the cointegration vector and are able to find support for PPP among 14 country pairs.[18] Wang uses ADF with Johansen for seven Asian countries over the recent floating period using monthly data and the dollar as base. The results suggest that on the one hand, the nominal exchange rate and the price indices are cointegrated and on the other hand, the PPP vector does not exist in the cointegration space.[19] This second result implies the restrictions of symmetry and proportionality are rejected, which means that the exchange rates do not move one to one with the relative price of two countries. Therefore, long run PPP does not appear to hold. Ramirez and Khan use the above techniques as well as an Error Correction Model (ECM) for five industrialized countries using monthly, quarterly and annual data for the period 1973-1996 using the dollar as base. Error correction models are useful because they reconcile the short run and long run behavior of variables involved. The cointegration test indicated that for all countries,

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[17] Murat Donganlar. "Testing the Long-Run Validity of Purchasing Power Parity for Asian Countries." Applied Economic Letters, 1999. Vol.6 p147

[18] Mehdi Salehizadeh, Robert Taylor. "A Test of Purchasing Power Parity for Emerging Economies." Journal of International Financial Markets, Institutions and Money, 1999. Vol.9 p183

[19] Ping Wang. "Testing PPP for Asian economies During the Recent Floating Period." Applied Economic Letters 2000, Vol. 7 p 547

the PPP hypothesis holds in the long run but not the short run. Further, the ECM suggested that the deviations of the actual exchange rate from its long-run PPP value were corrected in subsequent periods. Finally, the high frequency monthly data models did a better job of tracking the turning points of the actual data than the low frequency quarterly and yearly models.[20]

Zhou (1997) examines the long run validity of PPP for four high inflation countries using the Zivot and Andrews test to detect the time series behavior of the exchange rates and consumer price indices followed by Johansen's multivariate cointegration technique. The cointegration tests are conducted with the correction of the finite sample bias and the adjustment for trend breaks. The results show that during the recent floating exchange rate period the results are consistent with PPP, at least in weak form, in high inflation countries where the general price level movements overshadows the factors causing deviations from PPP.[21]

Soofi (1998) uses cointegration and fractional cointegration methods in determining the mean reverting properties of the parallel market exchange rate for several members of the Organization of Petroleum Exporting Countries (OPEC). Using monthly data from the Bretton Woods era with the dollar as base, the ADF and Geweke and Porter-Hudak (GPH) tests of stationarity are used. Autoregressive Integrated Moving Average (ARIMA) and Autoregressive Integrated Fractional Moving Average

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[20] Miguel D. Ramirez, Shahryar Khan. "A Cointegration Analysis of Purchasing Power Parity: 1973-96" International Advances in Economic Research, 1999. Vol.5 p369

[21] Su Zhou. "Purchasing Power Parity in High-inflation Countries: A Cointegration Analysis of Integrated Variables with Trend Breaks." Southern Economic Journal, 1997. Vol.64 p450

(ARFIMA) tests of cointegration are applied and reveal that no evidence of PPP is found using cointegration while four of nine OPEC countries support PPP using fractional cointegration.[22]

Choudhry (1999) also uses cointegration and fractional cointegration methods with monthly data from 1991-1996/97 between the U.S. and four high inflation Eastern European countries. The ADF, KPSS and GPH tests are used to test for unit roots, while the GPH and Harris-Inder test for cointegration. According to Harris and Inder the merit of the null hypothesis cointegration is more visible in models where the variables are believed to be cointegrated *a priori*. The test advocated by Harris and Inder is basically an extension of the test proposed by Engle and Granger, mixed with the KPSS unit root test. The results show no support for PPP using cointegration but found support using fractional cointegration. There is evidence of relative PPP among some countries but no evidence of absolute PPP.

Using a time series and panel data approach, Canzoneri et al. (1999) use ADF, GLS, Levin and Lin (LL) and Im-Pesaran-Shin (IPS) to test for stationarity and the Horvath and Watson test of cointegration. Horvath and Watson tests the null hypothesis that the nominal and PPP exchange rates are not cointegrated with a slope of 1.0. The LL test is basically a multivariate generalization of the standard DF test. The data tested is

[22] Abdol S. Soofi. "A Fractional Cointegration Test of Purchasing Power Parity: the Case of Selected Members of OPEC." Applied Financial Economics, 1998. Vol.8 p559

13 OECD countries with the dollar and the DM as base. The evidence on PPP is scarce for the dollar exchange rates while it is more favorable with the DM.[23]

Cheng (1999) reexamines the causality between the dollar and yen in a multivariate framework with the aid of cointegration and error-correction modeling for the 1951-1994 period. The PP tests and Johansen's tests are performed as well as Hsiao's version of Granger multivariate causality. Error correction modeling (ECM), VAR analysis and a super exogeneity test are also applied. Causality is found running from relative prices to exchange rates along with interest rates between the U.S. and Japan in the long run, which supports the long run PPP hypothesis.[24]

Gogas (2000) uses recent advances in the theory of nonstationary regressors and uses the Fisher and Seater as well as King and Watson tests to test the existence of long run PPP. Using quarterly data from 1973-1997 and the dollar based exchange rates for 16 OECD countries; the stationarity properties of the variables are tested using ADF and PP. The results show strong support for long run PPP using both cointegration tests.[25] A forthcoming paper by Serletis and Gogas also using the Fisher and Seater technique on 21 OECD countries using dollar based, DM based and Yen based exchange rates also finds strong evidence consistent with PPP. The results indicate that PPP is more likely to hold

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[23] Matthew B. Canzoneri, Robert E. Cumby, Behzad Diba. " Relative Labor Productivity and the Real Exchange Rate in the Long Run: Evidence for a Panel of OECD Countries." Journal of International Economics, 1999. Vol.47 p251

[24] Benjamin S. Cheng. "Beyond the Purchasing Power Parity: Testing for Cointegration and Causality between Exchange Rates, Prices and Interest Rate" Journal of International Money and Finance, 1999 Vol.18 p911

[25] Periklis Gogas. "PPP, Balanced Growth and Volatility Forecasting." Department of Economics, The University of Calgary, 2000 p17

between European countries and the United States and Japan than among European countries.[26]

Using a new econometric technique developed by Pesaran, Shin and Smith (PSS), the existence of the long run relationship underlying PPP can be tested regardless of whether the underlying variables are stationary, integrated or mutually cointegrated. Pesaran, Shin and Smith (2000) use this new technique to re-examine PPP as well as uncovered interest parity hypothesis for quarterly data from the period 1972-1987 under the maintained assumption of exogenously given foreign oil prices. The authors' results are encouraging in that the above test is likely to perform well in small samples and provide evidence in favor of PPP.[27]

Serletis and Coe (2000) also use the aforementioned technique to test for absolute and relative PPP during the recent flexible exchange rate period, using quarterly data for 21 OECD countries. Their results are consistent with most of the existing literature, which mostly shows the data rejects absolute PPP when the U.S. dollar is used as the base currency. There is some evidence, however, in favor of long run absolute PPP when the Japanese yen and the German mark are used as the base currency. However, the authors do provide overwhelming evidence in favor of long run relative PPP and their evidence is robust to the currency used as the base.[28]

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[26] Apostolos Serletis, Periklis Gogas. "New Tests of the Theory of Purchasing Power Parity." Mimeo, Department of Economics, The University of Calgary, 2000. p8

[27] M. Hashem Pesaran, Yongcheol Shin, Richard J. Smith. "Structural Analysis of Vector Error Correction Models with Exogenous I(1) Variables." Journal of Econometrics, 2000. Vol. 97 p330

[28] Patrick Coe, Apostolos Serletis. "Bounds Test of the Theory of Purchasing Power Parity." Department of Economics, University of Calgary, 2000 p9

One important paper that should be noted before concluding, is a paper by Alan M. Taylor, which does not correspond with either of the above two categories of popular testing methodologies. This paper does not actually test for PPP but instead attempts to identify the 'pitfalls' that authors encounter when trying to uncover PPP. He notes two key pitfalls that are repeatedly seen in the literature. The first pitfall Taylor calls 'Temporal Aggregation' and is related to the frequency of the data. Taylor asserts that higher frequency data needs to be discovered and utilized. The second pitfall is 'Linear Specification" and is caused by a failure to recognize nonlinear adjustment dynamics and the use of an inappropriate linear AR(1) specification. Taylor states that authors must, "consider the implications of nonlinear models that might deliver more rapid adjustments outside any 'bands of inaction.'"[29]

The above two sections constitute a concise summary of the recent empirical work done in the area of long run PPP. The next section attempts to draw some conclusions on areas for future research.

4.3. DRAWING CONCLUSIONS FROM THE LITERATURE

The purpose of the literature review is not merely to recite the literature that has been done in the area of PPP, but instead to identify successes and failures of empirical techniques and data selection. By identifying these successes/failures, future authors are

[29] Alan M. Taylor. "Potential Pitfalls For the Purchasing Power Parity Puzzle? Sampling and Specification Biases in Mean-Reversion Tests of the Law of One Price." NBER Working Paper Series #7577, 2000 p 19

able to build on past research and optimize future testing procedures. In the case of PPP, this task proves particularly complex because of the abundance of research available. However, some general conclusion can be made, though they are limited in that they lack unanimity among economists.

In testing the real exchange rate, it appears that PPP finds more support when panel data is used, rather than time series. This is because in situations where there is not enough time series variation to produce good power in unit root tests, a relatively small amount of cross-section variation can result in substantial improvement. Some of the more fundamental tests for time series data such as the Adjusted Dickey Fuller (ADF), Phillips Perron (PP) or KPSS tests have extremely limited success in providing evidence in favor of long run PPP. While panel data tests such as DFGLS do have success supporting long run PPP, there is still no explicit evidence that panel data is optimal for testing PPP.

When looking for a cointegrating relationship, the results are conflicting. Fractional cointegration appears to have more ability to explain PPP compared to cointegration. Again, those fundamental econometric cointegration techniques such as the Engle Granger and Johansen tests have little or no success finding evidence consistent with PPP. However, less common techniques such as the Shin version of KPSS, the PSS test or the Fisher and Seater test have had greater success uncovering results consistent with PPP. Unfortunately, none of the newer testing procedures comprise a significant body of work that might suggest that the new test is the best way to test PPP.

As far as the data specification is concerned, the research is extremely conflicting. Whether using monthly, quarterly or annual data, CPI or WPI, or limiting the sample period to the current float there is no significant, identifiable effect on the empirical results. A majority of authors chose the current float period but results were mixed for all sample periods. The periodicity of the data again provided inconsistent results, as did the choice of price index. However, there is some evidence in recent papers that suggests that increasing the periodicity of the data is more desirable. This is a fairly recent trend in the literature that stems from the new approach to PPP, which is more interested in the *half-life of deviations* as well as the *convergence speed* of PPP. Taylor endorses this emphasis on increasing the periodicity of the data because he believes that low periodicity contributes to bias the analysis towards findings of slow convergence and a real exchange rate that is a random walk. There is also a portion of the literature dedicated to examining PPP within different country groups. Popular categorizes include high inflation countries, developing countries and OECD countries. There is an increasing amount of work done in the area of high inflation countries because at high rates of inflation, nominal shocks dominate real shocks, whereas at low rates the opposite is true. This suggests that mean-reverting tendencies in real exchange rates are likely to be more evident at higher inflation rates. Yet there is no strong consensus from the empirical work that indicates this result is substantiated.

Thus, the conclusion reached from all of the above research is that the empirical technique, more so than the data specification, affects the outcome of the research. As

such, future research should not involve simply modifying the details of data while replicating empirical techniques but rather should concentrate on new empirical applications. Another area of concentration is to adhere to those pitfalls identified by Alan Taylor. That is, discovering higher frequency data as well as considering nonlinear models in the hopes of uncovering PPP. While the empirical conditions used to test for PPP are crucial, it is also important to remember the actual market framework in which the testing is being conducted. According to Taylor, "when testing for PPP of LOOP [the law of one price], model specification and data sampling should not proceed without consideration of the actual institutional context and logistical framework of markets."[30] Finally, a crucial observation that can be made from the above literature review is that there is very little consensus that comes out of the research as to the best approach for testing PPP. In the subsequent Chapter, we move on to consider the procedure that will be applied in this paper.

[30] Alan M. Taylor. "Potential Pitfalls For the Purchasing Power Parity Puzzle? Sampling and Specification Biases in Mean-Reversion Tests of the Law of One Price." NBER Working Paper Series #7577, 2000 p 1

Chapter III - DATA AND METHODOLOGY

1. INTRODUCTION

The purpose of this section is to describe in detail the data that will be utilized to test for the existence of Purchasing Power Parity. Also, this section incorporates a comprehensive discussion of the methodology to be employed, namely the Christiano and Fitzgerald band pass filter. The filter will be introduced and the subsequent procedures applied to the filtered data will be described. The next portion of this section will be dedicated to comparing the Christiano and Fitzgerald to similar filters, such as the Baxter-King filter and the Hodrick-Prescott filter. The purpose of the latter section is to illustrate that the Christiano and Fitzgerald filter is superior to both of the above techniques. The final portion of this section describes the Monte Carlo technique that is used in addition to the filter.

2. DATA

The data used in this paper is a selection of 10 countries, spanning different time series. One key feature of the data is that it covers over a century of time, making it one of the longest times series applications of purchasing power parity ever studied. The data was originally constructed by Alan M.Taylor and Maurice Obstfeld and generously donated for the purposes of this paper. The post 1948 series are taken from the IMF's

International Financial Statistics while the aforementioned authors interpolated the early series using other available data.

The data consists of annual exchange rates, E_{it}, measured in domestic currency units per U.S. dollar and price indices CPI_{it}, measured as consumer price deflators. All of the variables are transformed using logs, and thus denoted e_{it} = log E_{it} and cpi_{it} = log CPI_{it}. To test for the existence of PPP we are interested in using the price differential, which is the foreign price level minus the domestic price level (the U.S. price level), denoted $pdiff_{it}$. The index $i = 1...10$ encompasses the set of countries Canada, Denmark, Finland, Italy, Norway, Portugal, Sweden, Switzerland, United Kingdom and the United States. As previously mentioned, the length of each series varies across countries; specifically the starting date varies while all series end in 1999. Canada, Norway, United Kingdom and the United States all span 1870-1999. Denmark, Italy and Sweden span 1880-1999 while Finland covers 1881-1999. Finally, Portugal covers 1890-1999 while Switzerland has the smallest series beginning in 1892.

It is valuable to note that the interpolation techniques used to generate the above data may be ad hoc and yet necessary to allow any stationarity tests a reasonable opportunity with the data. This is particularly necessary if we consider the many instances where there is missing data after periods of dramatic inflation when it is expected that the real exchange rate would depreciate. Without interpolation during these periods, any subsequent mean reversion would be missed by the estimation procedure

and a bias against stationarity would transpire.[31] In other words, if data were not created for these years then the results would be distorted. In terms of the technique applied in this paper, band pass filtering, it is extremely advantageous to have data spanning a long time series to maximize the effectiveness of the filter. Using a filter to test for PPP, we are asking the filter to remove components of the data outside of the long run, that is, to leave the long run intact. As such, having the interpolated data, which provides a lengthy series, is invaluable to the success of this paper because we are left with a sufficient amount of data for analysis after filtering. The raw data in logarithmic form is presented in Graphs 1-9.

3. METHODOLOGY

Economists have a long history of employing the moving average technique to extract long-run trends from empirical data. Recently, macroeconomists have used the Hodrick-Prescott or Baxter-King high pass filter to extract high-frequency bands from macroeconomic data and simulated data. However, a new filter has been introduced, the Christiano and Fitzgerald filter, which is superior to both of the above techniques and hence applied to the data for Purchasing Power Parity for the purposes of this paper.

The interest in the different frequency components of data is not new in economics and has widespread applicability. Moreover, some economic hypotheses are fundamentally rooted in frequency domain theory. One example of frequency domain

[31] Alan M.Taylor "A Century of Purchasing Power Parity" National Bureau of Economic Research Working Paper Series #8012, 2000, p3

theory is the proposition that money growth and inflation are highly correlated in the long run and less correlated in the short run.

The notion that there are different frequency components in data is based on the theory of spectral analysis of time series. A key feature of spectral analysis, relative to other methodologies of decomposing time series, is that it does not require a commitment to any specific statistical model of the data. Rather it relies on the 'Spectral Representation Theorem', which states that *any* time series within a broad class can be decomposed into different frequency components. This theory also proposes a tool for extracting those components, namely the *ideal band pass filter*. The ideal band pass filter represents a linear transformation of the data. This transformation leaves the components of the data within a specified band of frequencies intact while eliminating all other components. Calling the above band pass filter 'ideal' reflects an important practical limitation. Literally for the band pass filter to be ideal, there must be an infinite amount of data available. Since, in practice, this is not possible for macroeconomic time series, an approximation is needed.

Christiano and Fitzgerald (1999) characterize and study the optimal linear approximation, assess alternative approaches and provide empirical illustrations. The optimal approximation to the band pass filter requires knowing the true time series representation of x_t, the observed sample. This representation must be estimated, since in practice it is unknown. The conclusion the authors reach is that for standard macroeconomic time series, a more straightforward approach that does not involve first

estimating a time series is sufficient. This approach uses the approximation that is optimal under the (most likely, false) assumption that the data is generated by a pure random walk. This procedure is nearly optimal for the type of time series that fit U.S. data on interest rates, unemployment, inflation and output.[32] As such, this approximation is nearly optimal for the data used in this paper.

3.1. THE CHRISTIANO AND FITZGERALD FILTER

The Christiano and Fitzgerald filter is easy to implement and is described as follows. To isolate the component of x_t with periods of oscillation between p_l and p_u, where $2 \leq p_l < p_u < \infty$, the recommended approximation of y_t, $\hat{y}_t$, is computed as follows:

$$\hat{y}_t = B_0 x_t + B_1 x_{t+1} + \ldots + B_{T-1-t} x_{T-1} + \tilde{B}_{T-t} x_T + B_1 x_{t-1} + \ldots + B_{t-2} x_2 + \tilde{B}_{t-1} x_1 \quad (1.1)$$

for $t = 3,4,\ldots,T-2$.

In (1.1),

$$B_j = \frac{\sin(jb) - \sin(ja)}{\pi j}, \; j \geq 1 \quad (1.2)$$

[32] Lawrence J. Christiano and Terry J. Fitzgerald. "The Band Pass Filter" Federal Reserve bank of

$$B_0 = \frac{b-a}{\pi}, a = \frac{2\pi}{p_u}, b = \frac{2\pi}{p_l}$$

Note that the recommended filter varies with time and is not symmetric in terms of future and past x_t's. The above filter can also be modified to impose stationarity and symmetry. Simply construct (1.1) so that $\hat{y}_t$ is a function of a fixed number, p, of leads and lags of x_t and compute the weights on the highest lead and lag using simple functions of the B_j's.

To calculate the ideal band pass filter, we consider the following orthogonal decomposition of the stochastic process, x_t:

$$x_t = y_t + \tilde{x}_t \qquad (1.3)$$

The process, y_t, has power only in frequencies belonging to the interval $\{(a, b) \cup (-b, -a)\} \varepsilon (-\pi, \pi)$. The process, $\tilde{x}_t$, has power only in the complement of this interval in $(-\pi, \pi)$. Here, $0 < a \leq b \leq \pi$. According to Christiano and Fitzgerald it is well known that,

$$y_t = B(L)x_t \qquad (1.4)$$

where the ideal band pass filter, B(L), has the following structure:

$$B(L) = \sum_{j=-\infty}^{\infty} B_j L^j, L^l x_t \equiv x_{t-1} \qquad (1.5)$$

where the B_j's are given by (1.2). The specification of the B_j's gives the following

$B(e^{-iw}) = 1$, for $w \in (a,b) \cup (-b,-a)$

$= 0$, otherwise.

The assumption that a > 0, implies, together with (1.5), that $B(L) = 0$. Note from (1.4) that to compute y_t using $B(L)$ requires an infinite number of observations on x_t.

Christiano and Fitzgerald go on to show that there is a 'projection problem' for each set of data, the derivation of which is beyond the scope of this paper. However, they show that for a given t, a closed form solution is available by formulating it in the frequency domain:

$$\min_{\hat{B}_j^{p,f}, j=-f....p} \int_{-\pi}^{\pi} | B(e^{-iw}) - \hat{B}^{p,f}(e^{-iw}) |^2 \, f_x(w) dw, \qquad (1.6)$$

Where $f_x(w)$ is the spectral density of x_t. This formulation of the problem emphasizes that the solution to the projection problem depends on the time series properties of the

data being filtered. This is true despite the fact that the ideal band pass filter is not dependant on the time series properties of the data.[33]

It is now possible to explore the quantitative importance of three factors in the solution to (1.5). Christiano and Fitzgerald examine the role of asymmetry and time nonstationarity of the $B_{p,f}$'s as well as the importance of knowing the details of the time representation of x_t. They arrive at the following conclusions. First, by minimizing the mean square error substantial gains come from allowing the filter weights to vary over time. These gains reflect that allowing stationarity dramatically increases the amount of information in x that can be used in estimating $\hat{y}_t$. Second, allowing for asymmetry in the filter weights increases the amount of information in x that can be used in constructing $\hat{y}_t$, but by a decreased amount. The above conditions thus prove to be valuable and are achieved with a very minor cost. Finally, the authors conclude that there is very little gain in knowing the precise details of the time series representation generating the x_t's. All of the above findings lead the authors to the general conclusion that, "an adequate, though not optimal, procedure for isolating frequency bands in macroeconomic time series is to proceed as if the data were a random walk and use filters that are optimal in that case."[34]

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[33] ibid. p7
[34] ibid. p12

3.2. COMPARISON OF FILTERS

Before proceeding with this section, it is relevant to briefly compare and contrast the Christiano and Fitzgerald filter to other popular filters commonly used in the literature, namely the Baxter-King and Hodrick-Prescott filters. The purpose of this exercise is to emphasize that the Christiano and Fitzgerald filter is more advanced.

One popular filter, created by Baxter and King (1999), proposes a finite moving-average approximation of an ideal band pass filter designed to pass through components of time series with fluctuations between 6 and 32 quarters.[35] The methodology of this fixed-lag, symmetric filter is comparable to the Christiano and Fitzgerald filter. However, the filters differ in three substantial ways. First, the approach to approximating the band pass filter differs between the two filters. While the Christiano and Fitzgerald filter attempts to minimize the mean square error criterion, Baxter and King use a different optimization criterion. Their optimization criterion requires that the approximating filter optimizes (1.6) with $f_x \equiv 1$, subject to the requirement, $\hat{B}(1) = 0$. Christiano and Fitzgerald consider this criterion and conclude that the representation is one in which the spectral density is flat over most frequencies and then rises sharply in the neighborhood of zero. Second, the Christiano and Fitzgerald filter provides formulas for the optimal approximation to the band pass filter that apply to a broad class of time series representations. This contrasts with the Baxter-King filter which is best suited for instances when the Near IID assumption is adequate. According to Christiano and

Fitzgerald, the expectation is the Near IID representation will not be well suited for many macroeconomic variables. Third, the Baxter-King filter works with symmetric, fixed lag filters. Christiano and Fitzgerald show that adopting filters that use all of the data, and are therefore asymmetric and time varying improves the estimate of y_t. From the above criticisms of the Baxter-King filter, the conclusion is that the Christiano and Fitzgerald filter is superior.

Another popular filter that can be compared is the Hodrick-Prescott (1997). The Hodrick-Prescott filter decomposes a time series into an additive cyclical component and a growth component.[36] One fundamental criticism of the Hodrick-Prescott filter is that while both filters (Christiano-Fitzgerald and Hodrick-Prescott) attempt to solve a particular projection problem, the Hodrick-Prescott filter is based on a particular statistical model of the data. This contributes to two major shortcomings: (i) the underlying model has interpretation difficulties like other trend-cycle decompositions. There is a weak link between the concepts of 'signal' and 'noise' the filters seek to extract from the data and the meaningful economic objects in standard business cycle models. (ii) When interpreting the Hodrick-Prescott filter the underlying statistical model must be taken seriously. This potentially gives rise to several estimation and model evaluation issues that the very general conditions of the Spectral Representation Theorem can avoid. A second criticism of the Hodrick-Prescott filter can be directed at the fact that it is a particular band pass filter. It has never been argued that the Hodrick-Prescott

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[35] Alain Guay and Pierre St-Amant. "Do the Hodrick-Prescott and Baxter-King Filters Provide a Good Approximation of Business Cycles" Center for Research on Economic Fluctuations and Employment, Working Paper No. 53 1997, p9

[36] ibid. p4

is an optimal approximation to this band pass filter. A third criticism of this filter is that it is a precise algorithm, which simply draws a smooth line through the data. Again, these criticisms provide evidence that the Christiano and Fitzgerald filter represents an improvement over previous filters, namely the Baxter-King and Hodrick-Prescott filters.

4. APPLICATION OF FILTER TO PPP DATA AND MONTE CARLO ESTIMATION

In the previous section, the Christiano and Fitzgerald filter was described in detail and evidence suggesting its dominance was presented. In this section, we specifically consider how the Christiano and Fitzgerald filter can be used with Purchasing Power Parity data. Recall, we have two variables; the log of the exchange rate denoted e_{it} and the log of the price differential denoted $pdiff_{it}$ for each of the 9 countries. The filter is applied to each country for three different frequencies, high frequency with periods of oscillation between 2 and 8 years, mid frequency with periods of oscillation between 8 and 20 years and low frequency with periods of oscillation between 20 and 150 years. These time frames correspond with business cycles. The graphs of the filtered data are presented in Graphs 10-19.

With the data filtered the question then becomes: what is the relevance of the filtered data? We are interested in the correlation between the two series filtered, that is, the correlation between the filtered exchange rate and price differential for each country. But since the distribution of the correlation coefficient using filtered data is unknown, it

is impossible to use any standard critical values and thus traditional confidence intervals cannot be applied. Thus a Monte Carlo technique is utilized to generate a confidence interval of correlation coefficients. Once the original data is filtered, this Monte Carlo technique allows us to investigate how the filtered series are related. Since data is filtered by a non-linear filtering technique, the distribution of the correlation coefficient is not known, as it would be in a conventional framework. Therefore, artificial data is created, 1000 times, filtered, and the empirical distribution of the correlation coefficient is determined. Thus, the procedure for this paper is to generate data from the original data, filter the new data and calculate a correlation coefficient for each band pass filter frequency. This process is repeated 1000 times to generate a confidence interval. Using this generated confidence interval, the correlation coefficients can now appropriately be compared.

The next step is to determine a means of comparison in order to establish if the results are consistent with PPP according to this testing procedure. While several options are available, we will concentrate on two slightly differing techniques. One simple way to empirically examine whether the results are consistent with PPP is to consider if the sample correlation coefficient is greater than the artificially generated coefficient. For the purposes of this paper, we will consider the 950^{th} observation of the artificial data, representing either acceptance/rejection of the null hypothesis with 95% confidence. This simple procedure is accomplished by ordering the artificial data in *ascending order* and taking the 950^{th} observation for comparison with the sample correlation coefficient. If the sample coefficient is greater than the 950^{th} observation then the null hypothesis can

be rejected. Recall that the null hypothesis states that there is no correlation between the exchange rate and the price differential for each country. For PPP to hold, the null hypothesis is rejected.

The other slight variation of the above technique is to calculate a '*rejection rate*'. To achieve this we need to calculate how many times the artificial statistic is greater than the sample statistic. Each time the artificial statistic is greater than the sample statistic, it is considered a rejection. We tabulate the number of rejections and divide by the total number of observations, in this case 1000, to calculate the rejection rate. The method described here essentially opposite to the previous method. Here a rejection implies PPP does not hold and so we would like the rejection rate to be low.

5. SUMMARY

Due to the wealth of material covered in the previous section it is worthwhile to summarize the key developments. The first portion of the section was dedicated to explaining the Christiano and Fitzgerald filter, both intuitively and empirically. Next, we noted the importance of comparing and contrasting previous filtering techniques with the intention of illustrating that the Christiano and Fitzgerald filter represents an improvement over the two most related filters, the Baxter-King and Hodrick-Prescott. Finally, we addressed the issue of how to properly deal with the filtered data and described the methodology used to test for PPP involving Monte Carlo estimation.

Now that the technique used to test for PPP has been discussed in detail, we can summarize the results derived from applying the Christiano and Fitzgerald filter to the countries in this paper. The next section is dedicated to presenting these results.

6. ESTIMATION RESULTS

In the previous section, the Christiano and Fitzgerald Filter was discussed in detail. This filter was applied to the 9 countries of interest here and correlation coefficients were documented. Then a Monte Carlo technique was used to generate confidence intervals that share the same statistical properties as the actual data. Using the artificial data, we can now determine whether or not the results are consistent with PPP using two similar techniques discussed in the previous section. The first technique involves ordering the artificial data in ascending order and taking the 950^{th} value for comparison. This 950^{th} observation can then be compared to the sample correlation coefficient and the null hypothesis can be accepted/rejected with 95% confidence. The other technique involves calculating a 'rejection rate.' In this technique, we are interested in the number of times the artificial statistic exceed the sample statistic. Once tallied, this number is divided by the total number of correlation coefficients to generate a rejection rate. For the purposes of this paper, both standards are applied to consider whether or not the results are consistent with PPP. We begin by documenting the results from the technique using the 950^{th} observation and subsequently the results from using a rejection rate.

Recall the countries used to examine PPP are Canada, Denmark, Finland, Italy, Norway, Portugal, Sweden, Switzerland, and the United Kingdom. All of the countries are used to determine if PPP holds with respect to the United States. Recall as well that the Christiano and Fitzgerald filter was applied for three different frequencies, short run; periods of oscillation between 2 and 8 years, mid run; periods of oscillation between 8 and 20 years and long run; periods of oscillation between 20 and 150 years. Thus for each country there will be three cases to consider. All of the results for both techniques are summarized in Table 1.

We begin with Canada. The results of the filtering are consistent with PPP for Canada in the long run. In other words, because the sample statistic is greater than the 950^{th} artificial statistic we can reject the null hypothesis of no correlation between the exchange rate and the price differential. For Denmark the results are inconclusive in that they suggest PPP holds in the *short run*. This is inconsistent with the theoretical foundations underlying PPP, which suggest that PPP is a long run proposition. A result that shows evidence consistent with PPP *ONLY* in the short run is not satisfactory. The results for Finland reveal that the results support PPP in the mid to long run. This result is satisfactory because no standard length of time for PPP to hold has ever been established. That is, the *long run* has never been explicitly defined. In this instance the result is satisfactory because *BOTH* the mid to long run have evidence in favor of PPP. The numbers of years that define the long run is unknown and may vary among countries. Thus, for Finland because there is evidence of PPP for the mid and long run this result is reasonable. For Italy, the results are consistent with PPP over all three time frames:

short, mid and long run. Again, since no optimal time frame has ever been established with respect to PPP and what defines the long run, we consider this result to be satisfactory. Norway provides inconclusive results in that PPP is deemed to hold only in the short run, which is theoretically objectionable. This result is unsatisfactory because results consistent with PPP are only derived for the short run. These results suggest that PPP is a short run, rather than a long run, proposition. For Portugal, the results are consistent with PPP over all time frames so the null hypothesis is rejected for all cases. Rejecting the null hypothesis implies results consistent with PPP for all time frames. Sweden is another example of inconclusive results since the results are again consistent with PPP in the short run. According to the results for Switzerland, there is no evidence of PPP for any time frame. This is the only instance among all of the countries for which there is no evidence of PPP. Thus, the null hypothesis could not be rejected at all for Switzerland. For the United Kingdom the results are conflicting. While the results are consistent with PPP in the long run, they also show evidence that PPP holds in the short run. As previously noted, the latter result is theoretically undesirable. In this case, the conflict exists because results consistent with PPP are derived in the short and long run, but not the mid run. The short run results are unsatisfactory while the long run results are satisfactory.

The above results provide mixed support for PPP. There are numerous instances where the results are consistent with long run PPP. However, there are also instances where the results violate the widely held belief that PPP is a long run proposition. However, it was noted that the long run has never been explicitly defined. For those

instances where evidence in favor of PPP was revealed across all time frames or revealed for both the mid and long run, we considered this a satisfactory result. Only in those instances where *either* the short run or the long run had results consistent with PPP did we consider these results unsatisfactory. There is little question that PPP is a long run proposition and as such it is theoretically unlikely for the results to be consistent with PPP in the short run. In the next section, we consider whether or not the technique using the 'rejection rate' can shed more light on the PPP relationships between the countries in question.

In order to find support for PPP, we now consider another technique, which uses a 'rejection rate.' The methodology behind the 'rejection rate' has already been explained above. Note that evidence in favor of PPP is revealed by a low rejection rate. Again, we begin with Canada. For both the short run and mid run, the rejection rate is 1, or in other words 1000 out of 1000 coefficients are rejected. For the long run the rejection rate is 0.047, which suggests the results are consistent with PPP in the long run. These results are similar to the results derived above using the other technique. For Denmark, in the short run the rejection rate is 0.0001, which corroborates the result from the above technique. However, this conclusion violates the accepted conditions under which PPP can hold. For the mid and long run, the reject rate is 1, implying no evidence of PPP. Since evidence in favor of PPP is only found in the short run, this result is unsatisfactory. For Finland the rejection rate is 0.981 for the short run, suggesting no PPP relationship. For the mid run, the rejection rate is 0.017 and for the long run the rejection rate is 0, both of which suggest the presence of PPP. For Finland, we get the desired conclusion

because the results are consistent with PPP across both the mid and long run. Recall from the previous section it was noted that the long run had never been explicitly defined in terms of years. Hence, results consistent with PPP in both the mid and long run do not violate the theoretical belief that PPP is a long run proposition. These results correspond to the results derived for Finland using the other technique. Italy has a rejection rate of 0 for all three time frames; thus there is evidence in favor of PPP. Since there is a low rejection rate for all three time frames and it is unknown what constitutes the long run, we consider this to be evidence in favor of PPP. Norway, like Denmark, suggests that PPP only holds in the short run. The rejection rate is 0.002 for the short run and 1 for both the mid and long run. Since results consistent with PPP only exist in the short run, the notion that PPP is a long run proposition is violated. For Portugal, the rejection rate is low for all three time frames, with rejection rate of 0.0001, 0 and 0 respectively. A low rejection rate across all three time frames suggests results consistent with PPP. Sweden has rejection rates that are less easy to interpret. In the short run, the rejection rate is 0.024, which clearly suggests the results are consistent with PPP in the short run, though theoretically unacceptable. In the mid run, the rejection rate is 0.334 and for the long run the rejection rate is 0.468, so the existence of PPP is unclear. Similarly for Switzerland the results are somewhat ambiguous. The short, mid and long runs have rejection rates of 0.308, 0.630 and 0.912 respectively. This suggests that the results are consistent with PPP in the short run but not the long run, which is not a desirable result. No evidence in favor of PPP was derived using the other technique above. For the United Kingdom, the short run has a rejection rate of 0.0001 while the mid run has a rejection rate of 0.344. The long run has a rejection rate of 0.022. These results are consistent with PPP across

all three time frames if we consider the rejection rate in the mid run, 0.344, low enough to constitute a rejection. If 0.344 is considered a rejection, then these results differ from results obtained using the above technique.

Now that the results from both techniques have been presented, it is worthwhile to compare the two. Not surprisingly, the two techniques provide similar results. In fact, for the first six countries discussed above, Canada, Denmark, Finland, Italy, Norway and Portugal the two techniques reveal identical results. However, for the remaining three countries, Sweden, Switzerland and the United Kingdom these results are more difficult to interpret. Specifically, using the rejection rate, it is hard to determine what constitutes a strong rejection, making it difficult for a conclusion to be drawn about PPP.

In terms of drawing conclusions, results consistent with PPP exist for Canada, Finland, Italy, Portugal and the United Kingdom when we use the 950^{th} coefficient for comparison. For all of the countries, except Switzerland, some evidence of PPP is derived, however since PPP is a long run proposition, we must disregard those results that violate this theoretical belief.

When using the rejection rate technique, the results are consistent with PPP for Canada, Finland, Italy, Portugal, Sweden, and the United Kingdom. The rejection rate is slightly more difficult to interpret, as we discussed above, because there is no standard available that dictates what makes a strong rejection, or what constitutes a rejection at all.

Another important consideration is the graphs of the filtered data for each country, Graphs 10-19. The graphs of the filtered data are intended to further substantiate the results obtained using the two techniques above. Recall that the exchange rate and price series were filtered three times according to different business cycle lengths. Recall as well that, in general, a filter removes certain components of the data while leaving the remainder for analysis. For each series, a high, mid and long frequency of the data was removed; leaving data that corresponds with the short, mid and long run respectively. Each country has three graphs, the first graph represent the short run, the second graph represents the mid run and the third graph represents the long run. Since PPP is a long run proposition, we would expect to see the two graphed series, price differential and exchange rate, to follow the same path in the third graph. However, since the long run has never been explicitly defined, it is considered acceptable if the filtered series follow the same path in *BOTH* the mid and long run graphs, or in *ALL* of the time frames (short, mid and long run).

Beginning with Canada, we can observe that in the long run, which is in the third graph, the two series follow the same path over the time horizon. This observation is consistent with the results derived above. For Denmark, the graph of the long run shows that the price differential and exchange rate series follow the same trajectory over time. Again, this echoes the conclusions reached above. Finland, Italy and Portugal all have long run graphs with near perfect symmetry between the two series. The mid run graphs also show the two variables following the same course and for Portugal, this is true for the short run graph as well. The results for all of these countries are in harmony with the

results derived above using both empirical techniques. The three graphs for Norway are hard to interpret. The price and exchange rate series do not follow the same path in an obvious way. The conclusions reached using the two techniques above find evidence of PPP in the short run. This result is difficult to substantiate graphically because the short run graph has a lot of vacillation and it is challenging to visually identify a common trend. For Sweden, Switzerland and the United Kingdom, the graphs are difficult to interpret. These results are similar to the inconclusive results obtained by the empirical tests.

The conclusion that is reached from an examination of the graphs is the graphs reinforce the results empirically derived. The graphs cannot be used as meaningful evidence for or against PPP independently, but used in conjunction with other tests they provide additional weight to the conclusions reached.

Chapter IV – SYNOPSIS & POLICY IMPLICATIONS

Historically, despite its immense appeal as an equilibrating mechanism for prices and exchange rates, PPP has lacked unanimous support, not only empirically but also theoretically. This was evidenced in Chapter I, when the limitations faced by PPP were introduced as well as the strong tendency for previous work to reject the PPP hypothesis. However, what was central to this thesis was the emphasis on applying a new and innovative technique in the hopes of uncovering PPP and not repeating previous techniques that proved unsuccessful. This original application of a filter to data for PPP has proved successful as evidence of long run PPP was derived for several countries.

The first chapter initially presented some historical background of the PPP doctrine, after which it considered some theoretical shortcoming of PPP. Considered there was the (im) practicality of assuming that prices between different countries, once denoted in the same currency and given a sufficient lapse of time, would eventually equate due to arbitrage. Considerations looked at there were: the limitations of using a price index, external costs, the role of asset markets in altering exchange rates independent of relative prices, impediments to international trade and the inaccuracy of forecasting future prices.

Having provided a brief overview of the limitations of the theory, Chapter I documented the progression of the empirical work aimed at testing PPP. Next, we considered why a new paper on PPP would be warranted. The motivation for this paper

was then discussed as well as the original methodology to be employed. It is due to this original econometric methodology as well and the long data series used, that this paper represents a worthwhile contribution.

Chapter II discusses the theoretical foundations of PPP. The three different concepts of PPP are presented in detail. Once the concepts were established, we discussed the testing methodologies that were used. Having presented, in some detail, the popular testing methodologies, we then took an in depth look at the literature that puts these methodologies into practice. Because there is such a vast body of literature surrounding PPP, the literature review was limited to fairly recent and relevant papers. From the literature review, we were left with the incentive for a new and innovative attempt at empirically testing PPP.

Chapter III, outlined the data and technique applied in this paper. The data specifications and sources were presented. Next we introduced the Christiano and Fitzgerald filter and showed its mathematical derivation. This filter was then compared with similar popular filters to show its superiority. The standards used for evaluating whether or not the results are consistent with PPP were presented. In addition to the filter, the precise technique used, including Monte Carlo estimation, was also presented. Having set out the theoretical foundations, not only for the concept of PPP but also for the test method to be relied on, empirical estimation was then pursued. The results for each country were presented and summarized.

What was gained from the above Chapters was that the Christiano and Fitzgerald filter represents an improvement of past popular techniques. Long run PPP was uncovered for several countries, which contradicts the previous lack of support presented in the literature. The evidence from Canada, Finland, Italy, Portugal, Sweden and the United Kingdom is consistent with Purchasing Power Parity with the United States. The empirical results correspond with the graphical results presented in Graphs 10-19. A close examination of these graphs reveals the same conclusion as the Monte Carlo technique. The results presented here cannot be accurately compared with others because this technique has never been applied to PPP

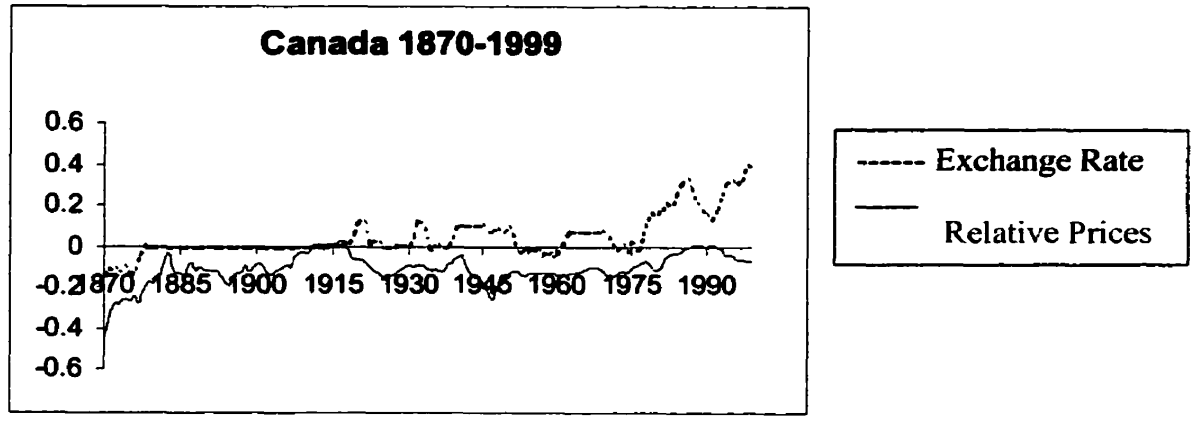
With such encouraging results, it is clear that the application of the Christiano and Fitzgerald was a necessary and worthwhile endeavor to breath new life into the topic of PPP. Perhaps some of the recent disinterest in the topic of PPP stems from the repetition of techniques that have been published since the origin of PPP. Applying new and innovative econometric tests is clearly necessary to find evidence of PPP. The technique used here provides countless areas for further investigation.

In terms of policy implications, recall the PPP doctrine is one of exchange rate determination. Thus there is room for government and monetary policy makers to affect exchange rates thought price manipulation. One tentative policy implication of these results is that if countries can stabilize their interest rates, then two countries may be able to stabilize their exchange rates.

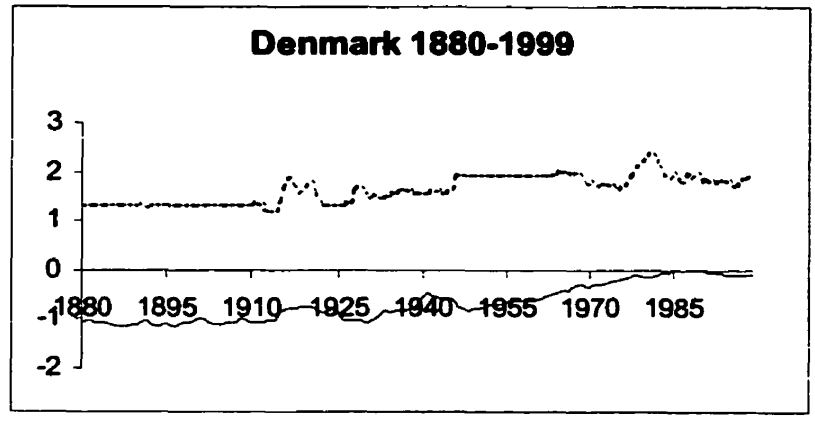
There exists a well known conflict facing policy makers when choosing between three competing objectives, (i) a fixed exchange rate, (ii) capital mobility and (iii) activist monetary policy, where only two of the three are feasible. Further study of Purchasing Power Parity undoubtedly has important ramifications for enabling policy makers to select which of the two objectives are most necessary to improve macroeconomic conditions. Purchasing Power Parity encompasses the key variables involved in monetary policy, namely price levels and exchange rates and thus it is reasonable that policy makers should be completely informed of the interaction between these variables.

GRAPHS 1-9 EXCHANGE RATE AND RELATIVE PRICES FOR EACH COUNTRY.

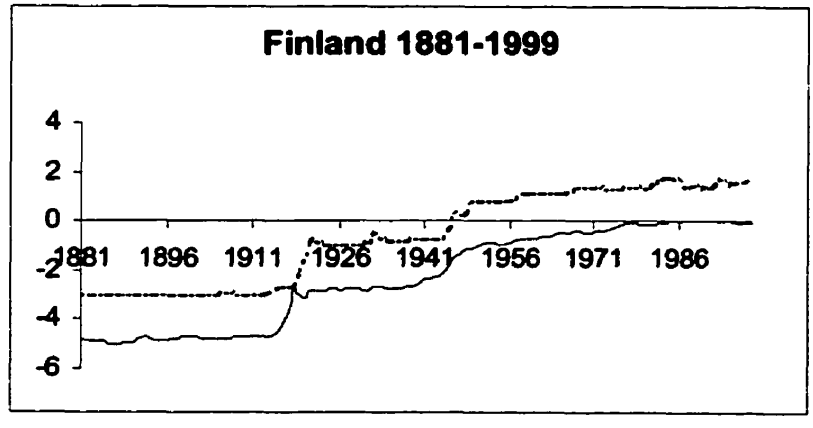
1- Exchange Rate and Relative Prices for Canada



2- Exchange Rate and Relative Prices for Denmark

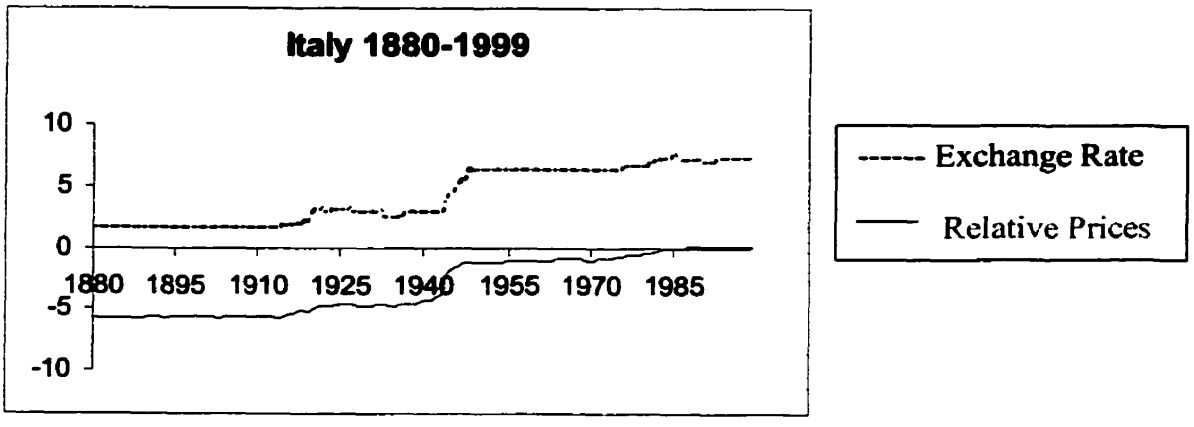


3- Exchange Rate and Relative Prices for Finland

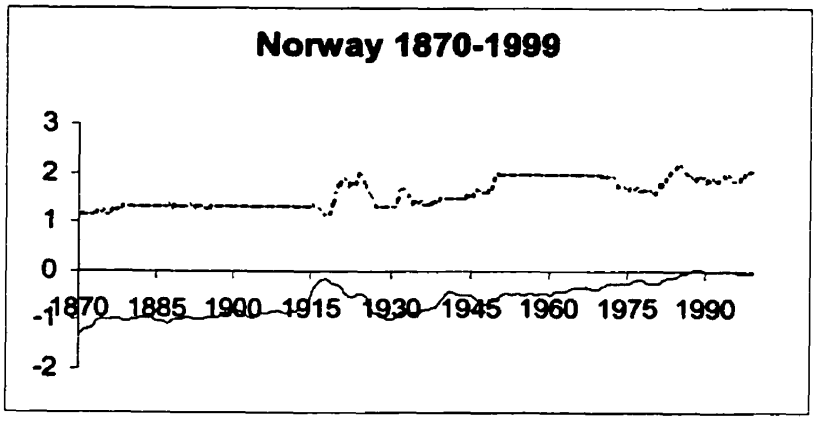


Note that the dashed line represents the exchange rate while the solid line represents relative prices.

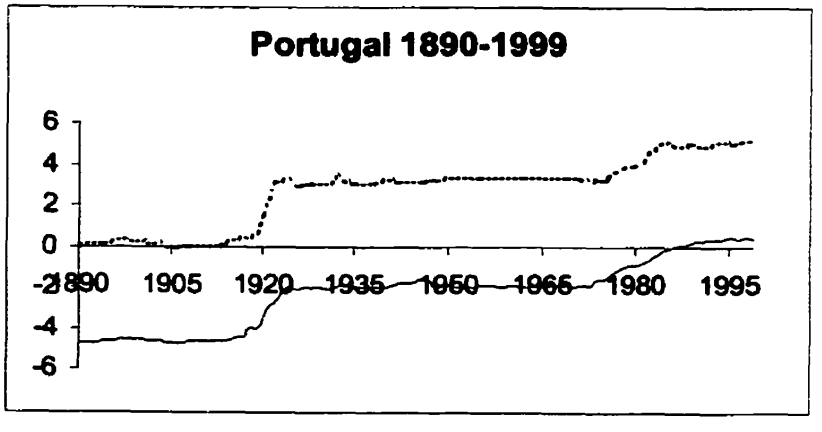
4- Exchange Rate and Relative Prices for Italy



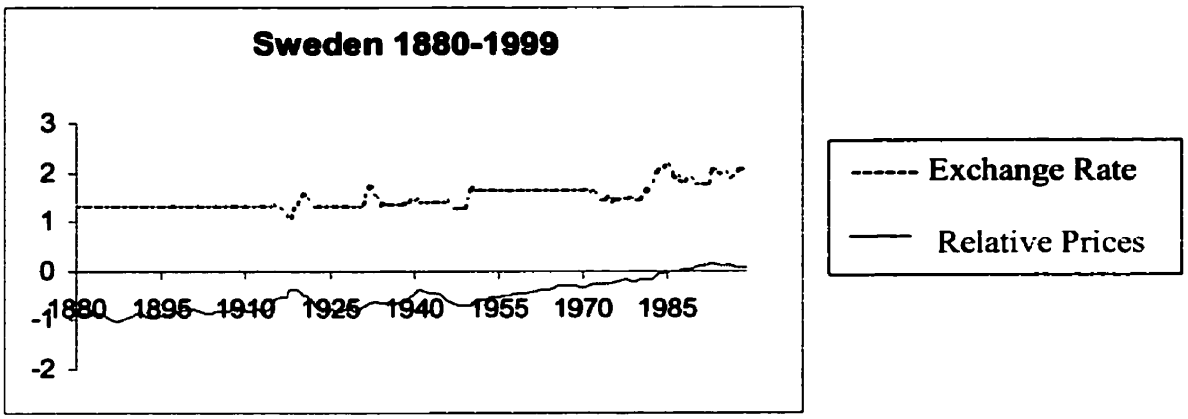
5- Exchange Rate and Relative Prices for Norway



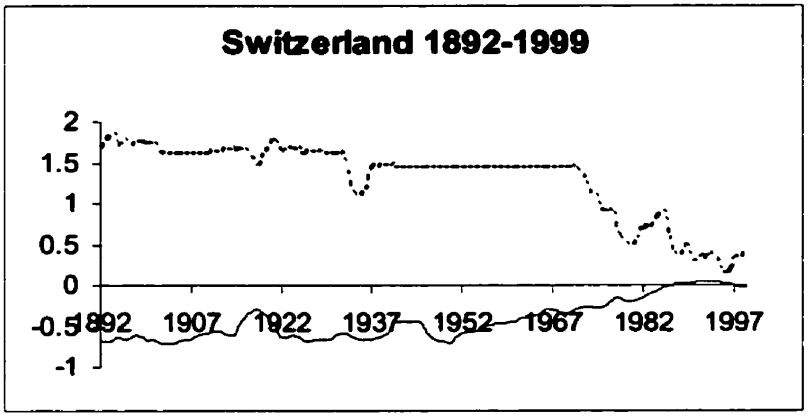
6- Exchange Rate and Relative Prices for Portugal



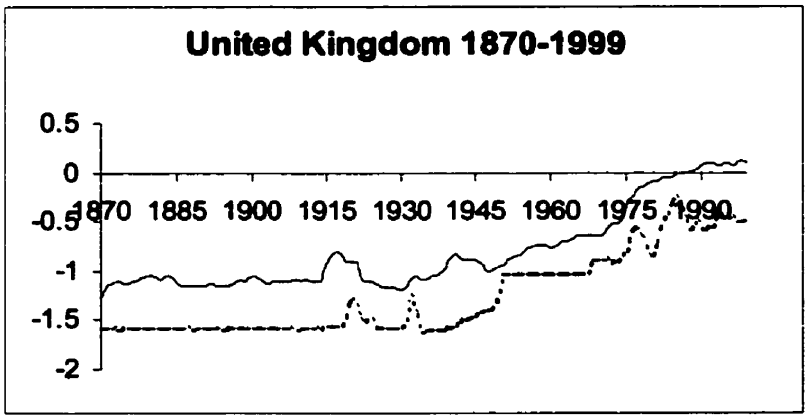
7- Exchange Rate and Relative Prices for Sweden



8- Exchange Rate and Relative Prices for Switzerland

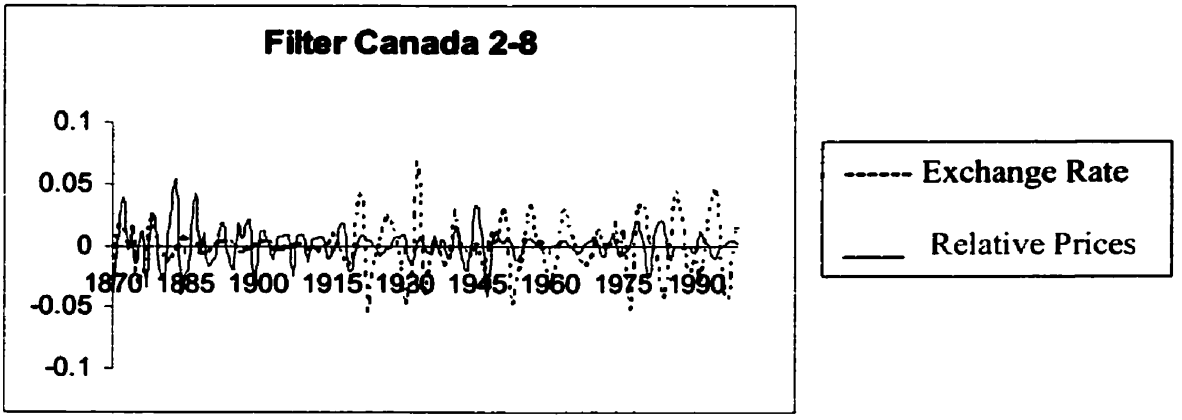


9- Exchange Rate and Relative Prices for United Kingdom

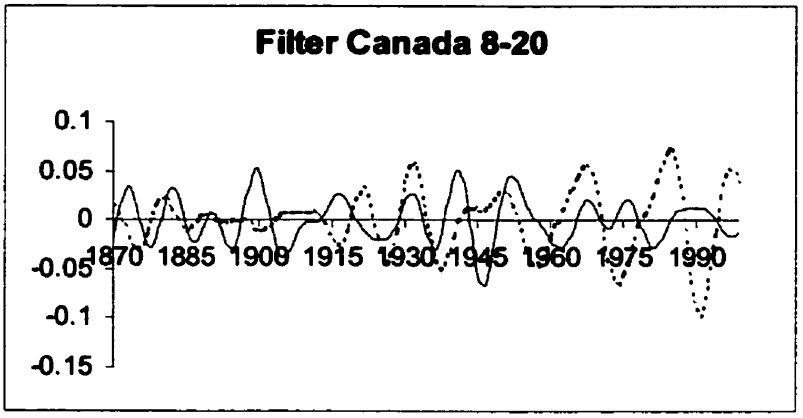


GRAPHS 10-19 FILTERED DATA FOR EACH COUNTRY

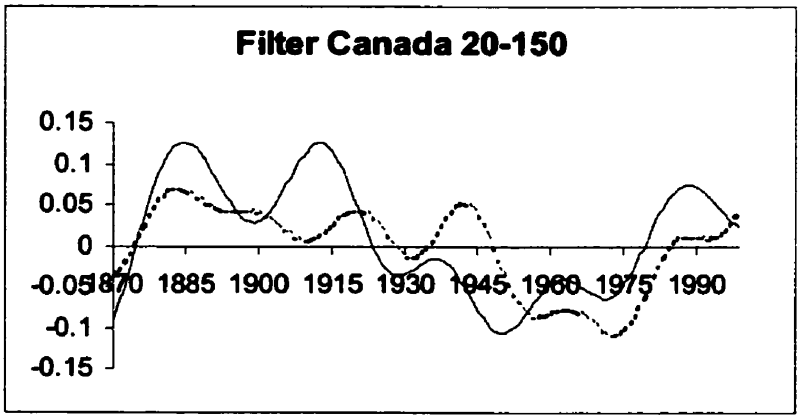
10a – Filtered Exchange Rate and Relative Prices for Canada



10b – Filtered Exchange Rate and Relative Prices for Canada

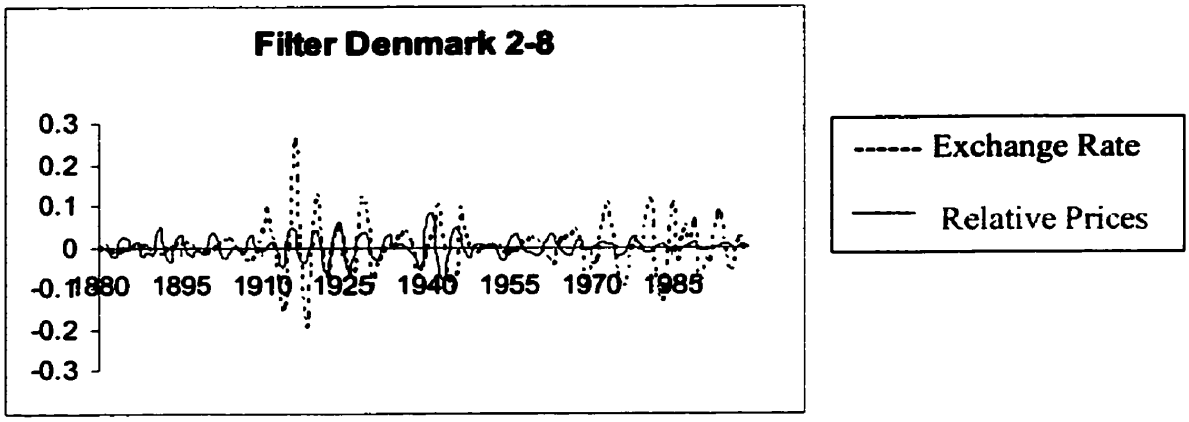


10c – Filtered Exchange Rate and Relative Prices for Canada

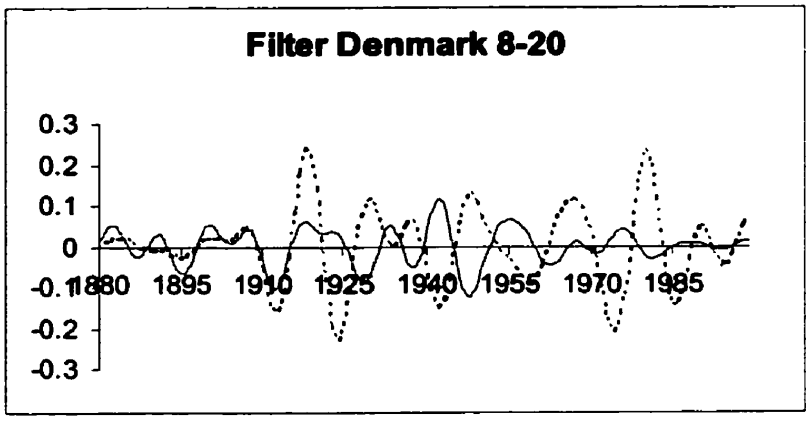


Note the dashed line represents the exchange rate while the solid line represents relative prices.

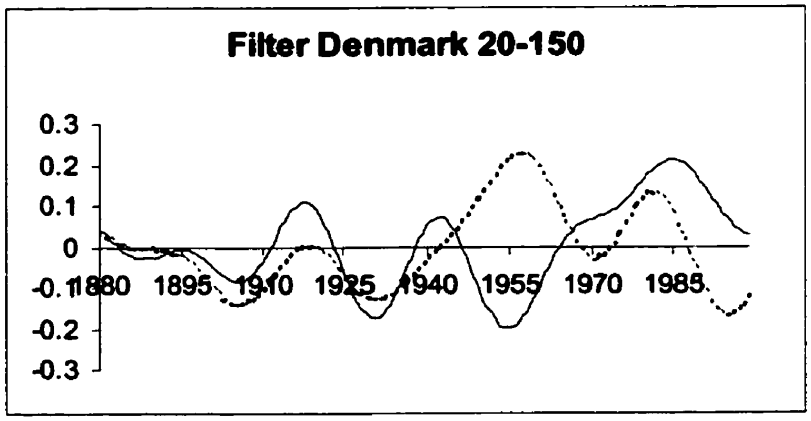
11a – Filtered Exchange Rate and Relative Prices for Denmark



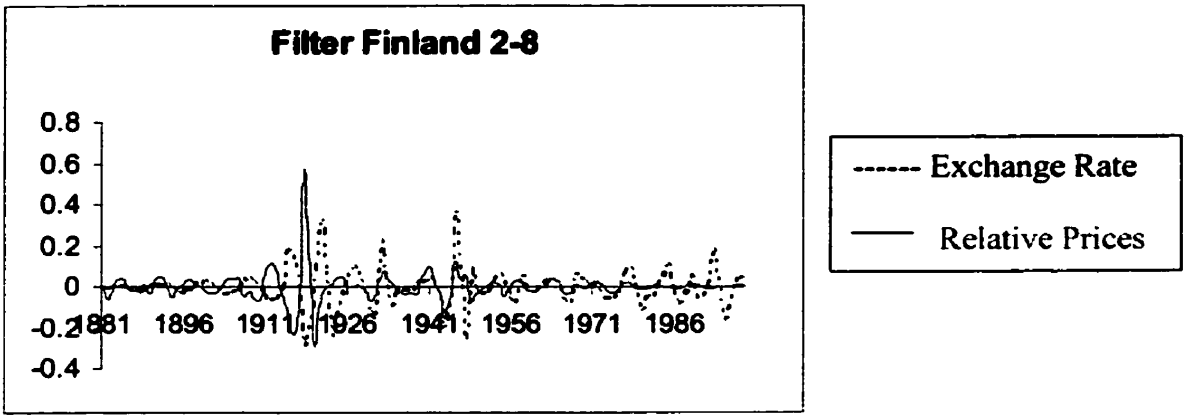
11b – Filtered Exchange Rate and Relative Prices for Denmark



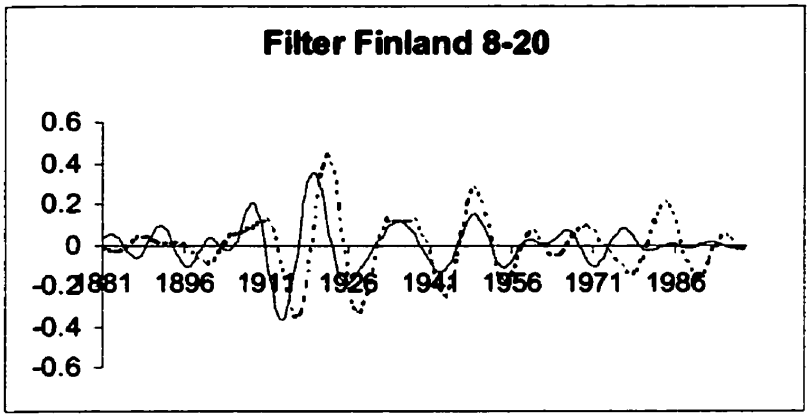
11c – Filtered Exchange Rate and Relative Prices for Denmark



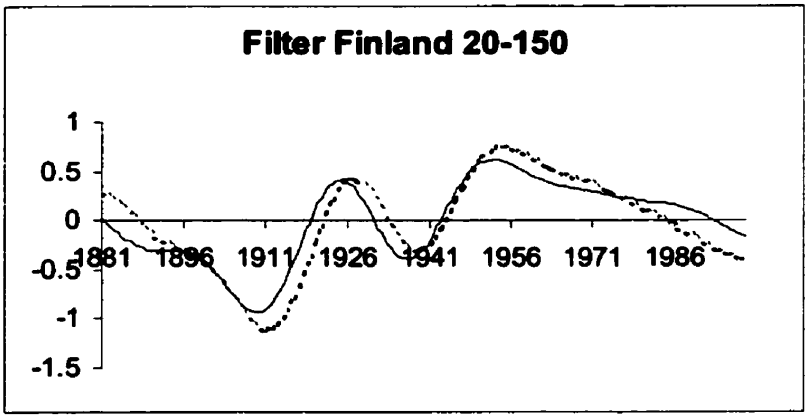
12a – Filtered Exchange Rate and Relative Prices for Finland



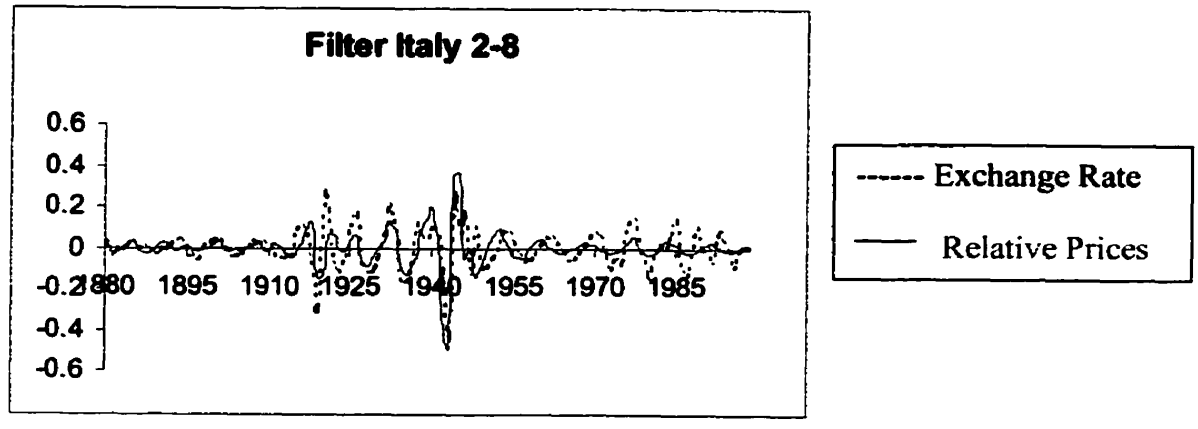
12b – Filtered Exchange Rate and Relative Prices for Finland



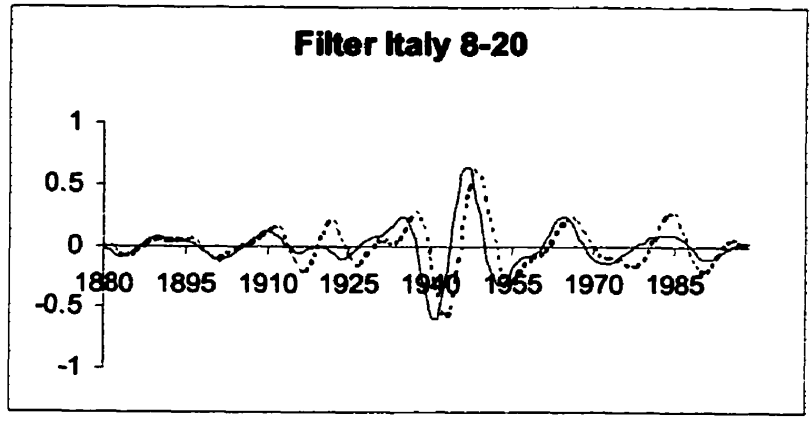
12c – Filtered Exchange Rate and Relative Prices for Finland



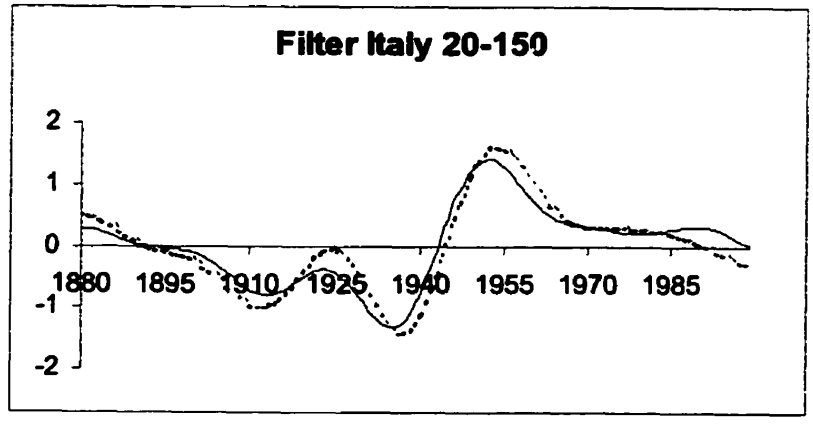
13a – Filtered Exchange Rate and Relative Prices for Italy



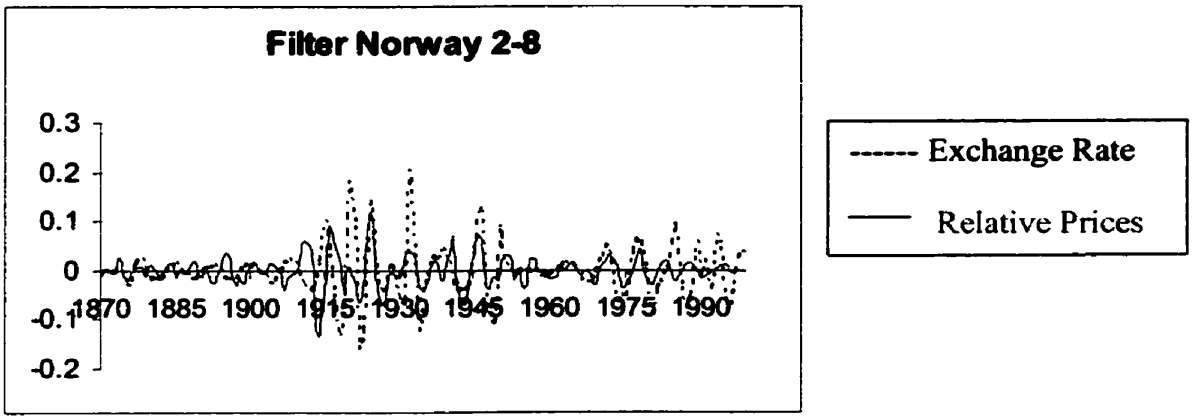
13b – Filtered Exchange Rate and Relative Prices for Italy



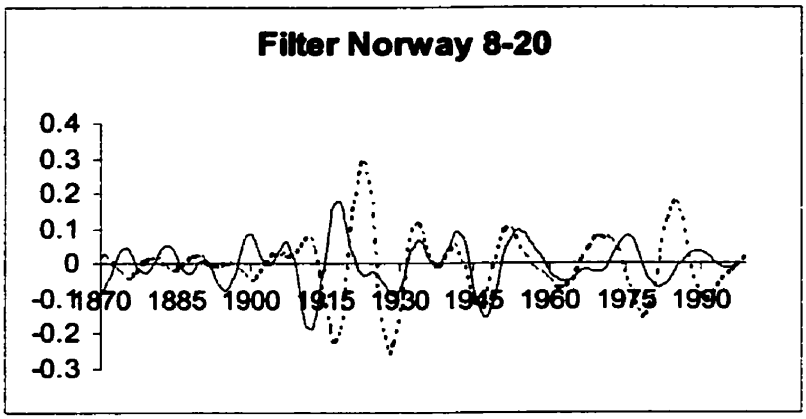
13c – Filtered Exchange Rate and Relative Prices for Italy



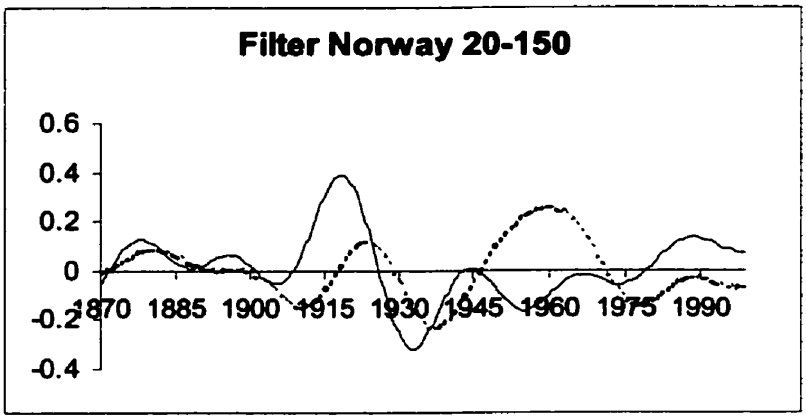
14a – Filtered Exchange Rate and Relative Prices for Norway



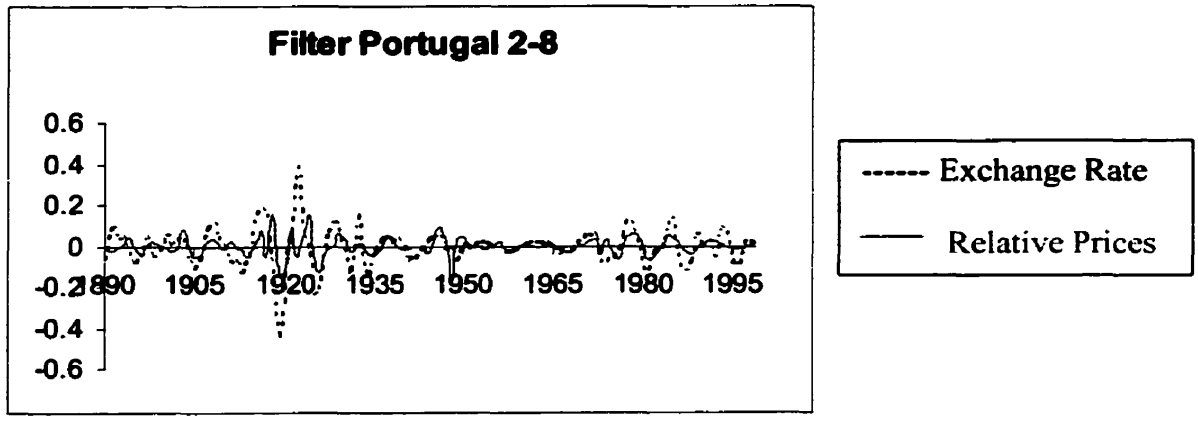
14b – Filtered Exchange Rate and Relative Prices for Norway



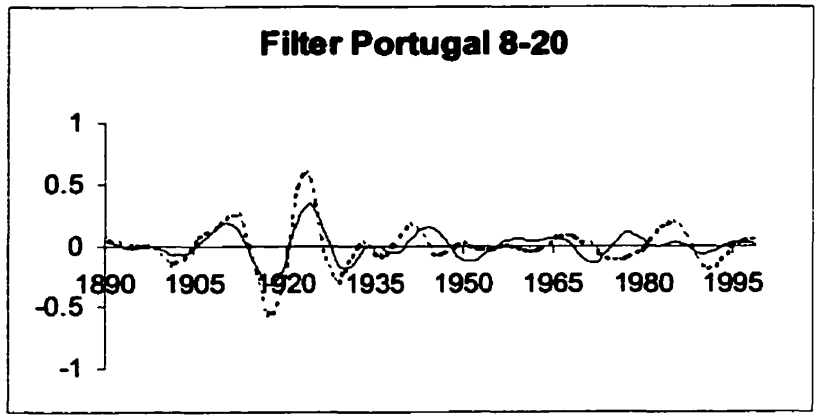
14c – Filtered Exchange Rate and Relative Prices for Norway



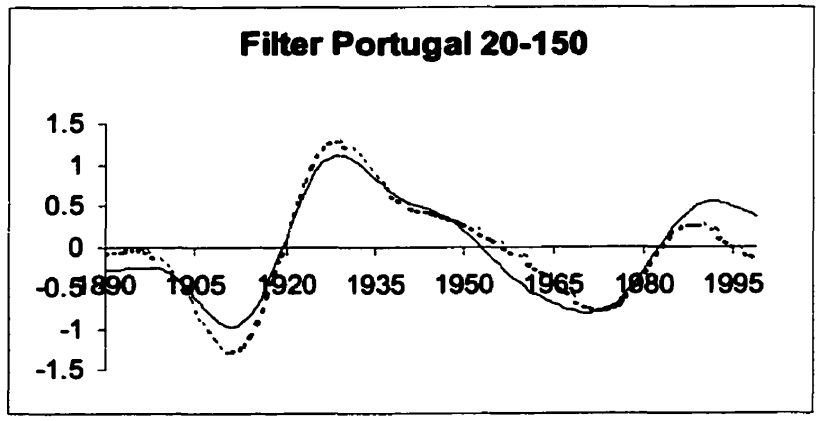
15a – Filtered Exchange Rate and Relative Prices for Portugal



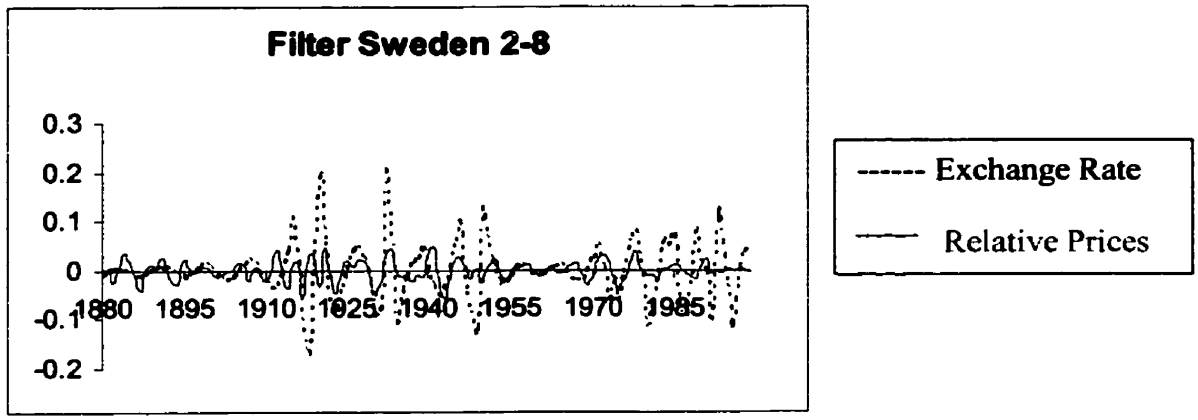
15b – Filtered Exchange Rate and Relative Prices for Portugal



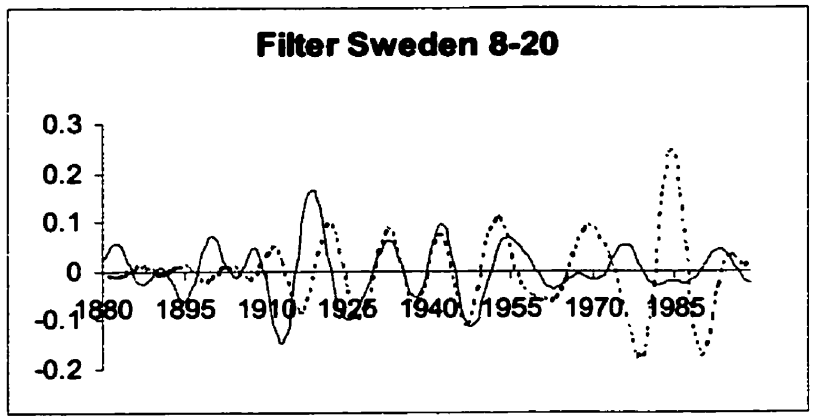
15c – Filtered Exchange Rate and Relative Prices for Portugal



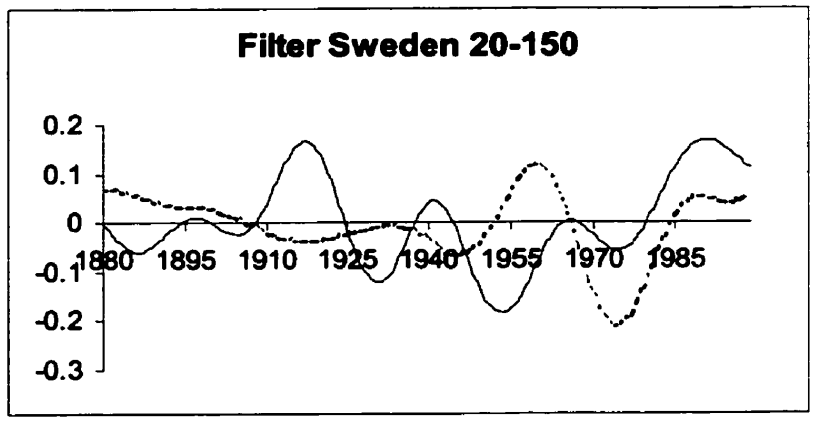
16a – Filtered Exchange Rate and Relative Prices for Sweden



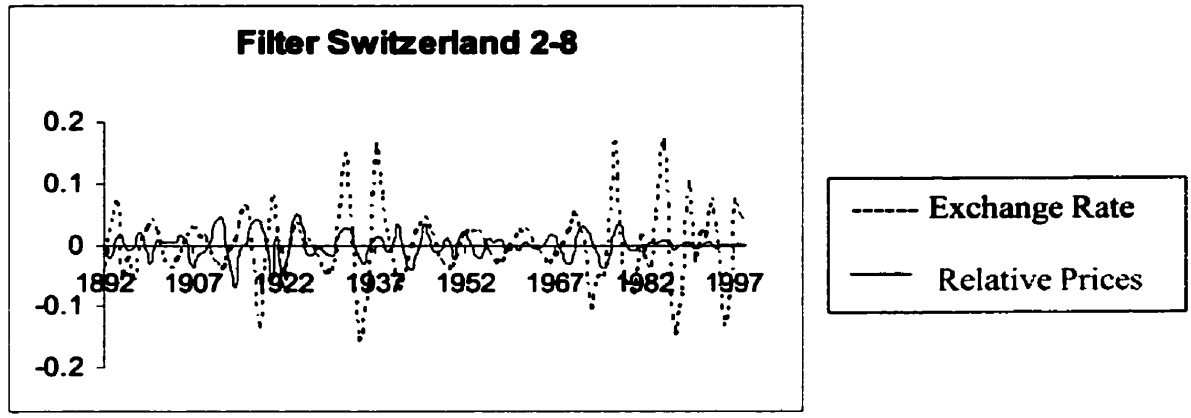
16b – Filtered Exchange Rate and Relative Prices for Sweden



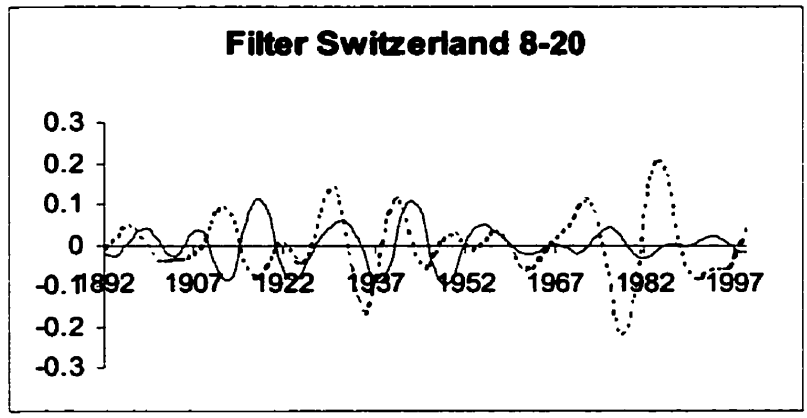
16c – Filtered Exchange Rate and Relative Prices for Sweden



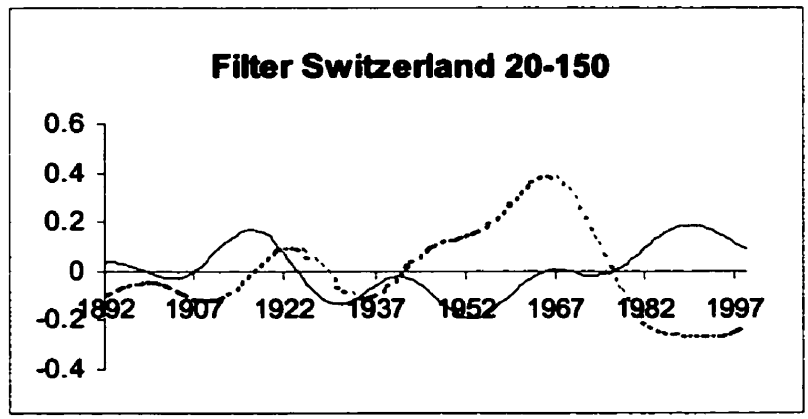
17a – Filtered Exchange Rate and Relative Prices for Switzerland



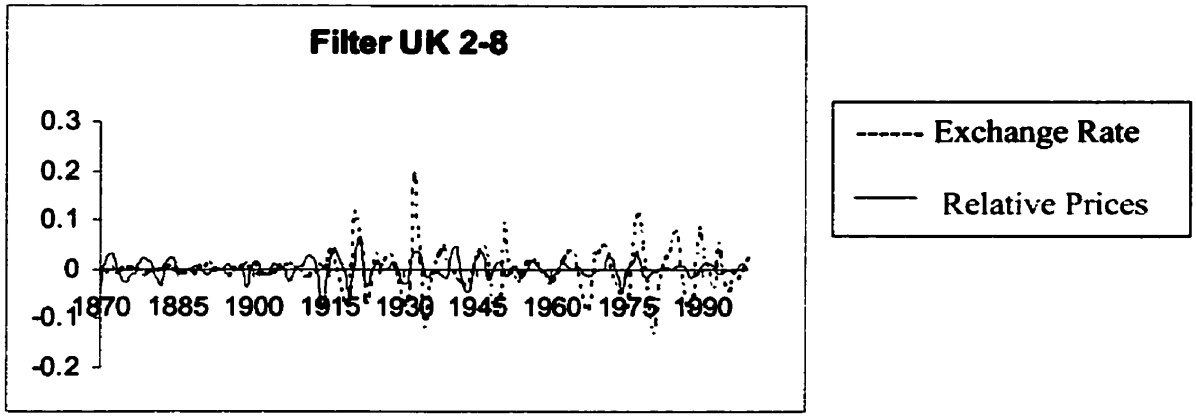
17b – Filtered Exchange Rate and Relative Prices for Switzerland



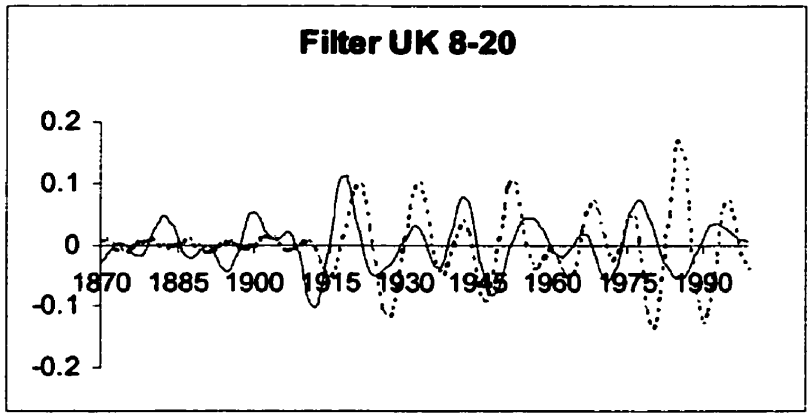
17c – Filtered Exchange Rate and Relative Prices for Switzerland



18a – Filtered Exchange Rate and Relative Prices for United Kingdom



18b – Filtered Exchange Rate and Relative Prices for United Kingdom



18c – Filtered Exchange Rate and Relative Prices for United Kingdom

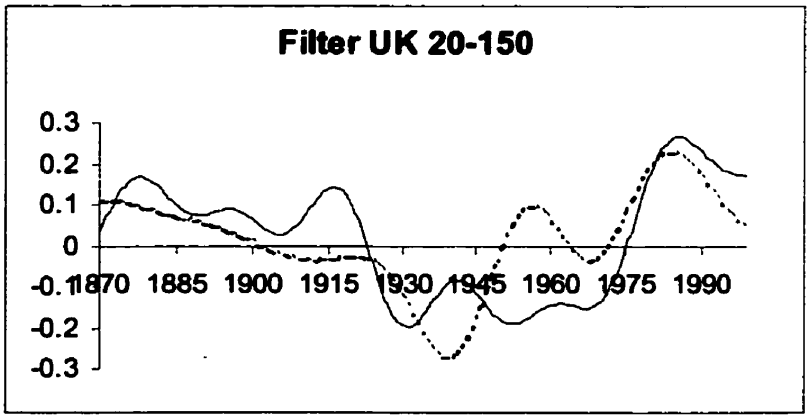


TABLE 1 - RESULTS

CANADA

-0.001147 **(Short Run)**	0.162471	1000
-0.052755 **(Mid Run)**	0.377705	1000
0.542675 **(Long Run)**	0.532043*	47

DENMARK

0.325928 **(Short Run)**	0.169968*	1
-0.174393 **(Mid Run)**	0.389412	1000
-0.066676 **(Long Run)**	0.540619	1000

FINLAND

-0.221030 **(Short Run)**	0.17435	981
0.484195 **(Mid Run)**	0.39326*	17
0.926201 **(Long Run)**	0.603773*	0

ITALY

0.549714 **(Short Run)**	0.183261*	0
0.658295 **(Mid Run)**	0.388786*	0
0.956539 **(Long Run)**	0.586272*	0

NORWAY

0.299458 **(Short Run)**	0.171355*	2
-0.042297 **(Mid Run)**	0.373371	1000
0.054544 **(Long Run)**	0.537505	1000

Note that * indicates the correlation coefficient is greater than the 950th artificial observation and thus the null hypothesis is rejected.

PORTUGAL

0.324471 **(Short Run)**	0.181979*	1
0.757162 **(Mid Run)**	0.411781*	0
0.944192 **(Long Run)**	0.629396*	0

SWEDEN

0.210537 **(Short Run)**	0.176769*	24
0.100738 **(Mid Run)**	0.382566	334
0.0066489 **(Long Run)**	0.560439	468

SWITZERLAND

0.054654 **(Short Run)**	0.190786	308
-0.097967 **(Mid Run)**	0.445552	630
-0.539006 **(Long Run)**	0.59349	912

UNITED KINGDOM

0.312959 **(Short Run)**	0.170277*	1
0.086766 **(Mid Run)**	0.364626	344
0.635031 **(Long Run)**	0.540412*	22

Note that * indicates the correlation coefficient is greater than the 950th artificial observation and thus the null hypothesis is rejected.

TABLE 2A – LITERATURE REVIEW SUMMARY: TESTING THE REAL EXCHANGE RATE

Wu (1997)	1979-1994, monthly, 11 OECD countries, base=dollar	ADF, PP and Zivot and Andrews test	No evidence using ADF & PP, Found evidenced using Zivot and Andrews
Papell (1997)	1973-1996, 20 countries with quarterly obs, 17 countries with monthly obs, base=dollar,DM	GLS, ADF	Evidence is stronger for larger rather than smaller panels, for monthly rather than quarterly and for the DM rather than the dollar
Meier (1997)	1979-1994, annual, 10 OECD countries, base=dollar	Panel data, GLS/SURE, DF, uses 'value added deflators for manufacturing' not CPI	European countries show evidence, Canada, Japan and UK show evidence
O'Connell (1998)	1972:2-1995:4, quarterly, 64 countries, base=member country price series.	GLS, FGLS	Found evidence
Maeso-Fernandez (1998)	1974-1994 monthly, 1948-1994 annual, 19 countries, CPI and WPI, base=dollar	Variance ratio test	Found more evidence when annual data and WPI is used
Anker (1999)	1973-1997, quarterly, 18 Industrialized countries, base=dollar, DM	Panel data, GLS, CPI and WPI	Found evidence using DM with both CPI and WPI, Weaker results with dollar for both CPI and WPI
Bleaney et al. (1999)	1972:1-1993:5, monthly, 5 countries, base=dollar	ADF, LM and Kalman Filter	Found no evidence using ADF and LM, Found evidence using Kalman Filter
Boyd and Smith (1999)	1966-1990, annual, 31 developing countries, base=dollar	Panel data and time series, Im, Pesaran and Shin unit root test (panel), ADF (time series)	Found more evidence when panel data is used
Guimaraes-Filho (1999)	1855-1990, annual, Brazil, base=dollar	ADF, PP, KPSS and Hasan and Koenker test	Found little or no evidence

Flores et al. (1999)	1973-1994, monthly, G10 countries plus Switzerland, base=dollar, DM	Multivariate framework with no imposed common speed of mean reversion	Found evidence for 6 countries, weaker results with DM, stronger results with dollar and European countries.
Kuo and Mikkola (1999)	1859-1992, annual, United Kingdom, base=dollar	ADF, DFGLS and P^u (null of unit root) Saikkonen and Luukkonen test (null of stationarity)	Found evidence
Bahmani-Oskooee, Mirzai (2000)	1973-1993, quarterly, 19 developed and 22 developing countries, base=dollar	ADF and KPSS	No evidence using ADF, Found evidenced using KPSS
Cheung and Lai (2000)	1973-1994, monthly, 94 countries, base=dollar	ADF, DFGLS, Fractional and Structural break test	Evidence is limited but more evidence with developing countries
Taylor (2000)	1892-1996, annual,20 countries, base=dollar	ADF, Johansen Likelihood Ratio test, ERS and DFGLS	Found evidence

TABLE 2B – LITERATURE REVIEW SUMMARY: TESTING COINTEGRATION

Zhou (1997)	1973-1995, Brazil, Israel, Mexico, Zaire	ADF, Zivot and Andrew test	Found evidence
Soofi (1998)	Different number of obs depending on country, monthly, 9 OPEC countries, base=dollar	ARFIMA, ML, GPH, R/S, MSSR	Found no evidence with cointegration, found evidence with fractional PPP
Canzoneri et al. (1999)	Different number of obs depending on country, annual, 13 OECD countries, base=dollar & DM	ADF, IPS, Levin & Lin, Horvath & Watson	Found little evidence with dollar, more evidence with DM
Cheng (1999)	1951-1994, annual, Japan, base=dollar	ECM, PP, Johansen, Hsiao version of Granger multivariate causality, VAR	Found evidence
Choudry (1999)	1991-1997, monthly, 4 high inflation Eastern European countries, base=dollar	ADF, KPSS, GPH and Harris Inder test	Found no evidence using cointegration but found evidence using fractional cointegration
Culver and Papell (1999)	1973-1996, quarterly, 21 industrialized countries, base=dollar	ADF, KPSS, Engle-Granger and Shin version of KPSS	Found little evidence using ADF and EG, Found more support using KPSS and Shin version of KPSS
Doganlar (1999)	1980-1995, quarterly, 5 Asian countries, base=dollar	ADF, EG, Johansen & Julius test	Found no evidence
Salehizadeh and Taylor (1999)	1975-1997, monthly, 27 countries, base=dollar	ADF, Johansen	Found evidence

Ramirez and Khan (1999)	1973-1996, monthly, quarterly, annual, 5 industrialized countries, base=dollar	ADF, Johansen, ECM,	Found evidence
Coe and Serletis (2000)	1973:1-1998:4, quarterly, 21 OECD countries, base=dollar, DM & Yen	PSS test	Found little evidence with dollar, more evidence with DM and Yen
Pesaran et al. (2000)	1972-1987, quarterly, United Kingdom, base=dollar	PSS test	Found evidence
Gogas (2000)	1973-1997, quarterly, 16 OECD countries, base=dollar	Fisher-Seater and King and Watson tests	Found evidence
Wang (2000)	Different number of obs depending on country, monthly, 7 Asian countries, base=varies	ADF, Johansen	Found no evidence
Serletis and Gogas (2001)	1973:1-1998:4, quarterly, 21 OECD countries, base=dollar, DM & Yen	ADF, Engle-Granger, Fisher and Seater test	Found evidence, evidence more likely to hold between European countries and the U.S., Japan than among European countries

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