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The PPP hypothesis in the US/China relationship. Fractional integration, time variation and data frequency

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ABSTRACT

This paper deals with the analysis of the Purchasing Power Parity (PPP) hypothesis in China by means of fractional integration or I(d) techniques. Using real exchange rates data between the Chinese Yuan and the US dollar, the results indicate that the estimated integration order d is generally larger than 1, which means that the PPP hypothesis in China does not hold in the long run over the sample period 1994M01 to 2010M11. Moreover, to check the stability of d across the sample period, we re-estimate it recursively over different subsample periods with 5-year and 10-year data frequencies respectively. The recursive estimated results show that after the structural change at the beginning of the sample period, the fractional differencing parameter d remains stable and generally larger than 1.

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1. INTRODUCTION

The theory of Purchasing Power Parity (PPP) is one of the central building blocks in the field of International Economics. Its concept was originally proposed in the 16th century, but since the 1970s, this theory has been a subject hotly debated (Taylor, 2006).

The research on PPP is extensive (see Taylor and Taylor, 2004 and Taylor, 2006 for recent surveys on PPP), but the conclusions are mixed depending on the different countries, data periods or econometric methodologies. In general, most people agree that PPP does not hold in the short run (or continually). However, the validity of the PPP hypothesis in the long run is still a controversial issue.

The major strand of the existing literature on PPP investigates the mean reversion of the real exchange rates in the long run. It is assumed that the long-run mean reversion of the real exchange rates implies that this variable is reverting to PPP level. Early studies applied the standard Dickey-Fuller (ADF) unit root tests (Dickey and Fuller, 1979) to test the hypothesis of mean reversion and often found a unit root in the real exchange rates, thus refuting PPP (Taylor, 2006). There are also many articles using cointegration analysis to investigate the PPP hypothesis, (in this case, testing for a stable long run equilibrium relationship between nominal exchange rates and prices), but there were conflicting results. Baillie and Selover (1987), Corbae and Ouliaris (1988), Mark (1990), Doganlar (1999) failed to find evidence of PPP; whereas the studies by Taylor and McMahon (1988), Enders (1988), Canarella, Pollard and Lai (1990), Heri and Theurillat (1990), Kim (1990), Kugler and Lenz (1993), and Culver and Papell (1999) reported evidence supportive of PPP. One reason for the early works failing to provide a convincing answer to the mean reversion problem of the real exchange rates is due to the low power of the unit root tests (Lothian and Taylor, 1997). To solve this problem some authors argue in favour of using long span data sets (Frankel, 1986; Edison, 1987; Lothian and Taylor, 1996; Engel and Kim, 1999; Taylor, 2002; Lothian and Taylor, 2008). Another strategy is to apply panel unit root tests and cointegration analysis (Abuaf and Jorion, 1990; Wu 1996; O'Connell, 1998; Flood and Taylor, 1996; Taylor and Sarno, 1998; Wu and Chen, 1999; Luintel 2000; Wu and Wu, 2001; etc.).

But there is an alternative feasible approach to test the PPP hypothesis, which employs models based on fractional integration. Using R/S analysis, Booth, Kaen and Koveos (1982) discovered a positive long-term dependence for several exchange rates during the flexible regime but negative dependence in the fixed period. Later, Cheung (1993) also found evidence of long memory (fractional integration) in the exchange rates. Both articles suggested that the models to study the behavior of exchange rates should be able to depict the long memory of the data. Moreover, as pointed out by Diebold et al. (1991) and Cheung and Lai (1993) and others, the lower frequency dynamics of the real exchange rates makes fractional integration analysis more desirable to test the PPP theory than the traditional unit root tests.

Gil-Alana and Hualde (2009) pointed out that the issue behind testing the PPP hypothesis is to determine whether the real exchange rates deviations from the PPP level are transitory or permanent, which implies that the real exchange rates will slowly revert to their parity value under the PPP hypothesis, or in terms of fractional integration, the order of integration will be smaller than one. Diebold et al. (1991) applied various tests of fractional integration to analyze the real exchange rates under the gold standard and found that PPP held in the long run for each exchange rate studied. Cheung and Lai (1993) applied single techniques of fractional cointegration on historical data for the 1914-1989 period and found evidence to support PPP as a long run phenomenon. Gil-Alana (2000) applied a version of Robinson's (1994) tests to analyze PPP in the real exchange rates between US and five industrialized countries and observed mean reversion of the real exchange rates in all countries if the disturbances were weakly autocorrelated. Caporale and Gil-Alana (2004) applied fractional integration and cointegration techniques to model the DM/dollar and the yen/dollar real exchange rates and discovered that mean reversion occured in each series. Masih and Masih (2004) applied fractional cointegration to examine the long run relationship between quarterly consumer price indices and bilateral exchange rates of the Australian dollar and seven major OECD trading partners and also found evidence in support of long-run PPP. Yoon (2009) applied the Exact Local Whittle estimators in Shimotsu and Phillips (2005) to estimate the long memory parameters of the real exchange rates for more than 100 years in 16 developed countries and concluded that PPP is valid in most of the countries studied. Additional papers on exchange rate dynamics using fractional integration and cointegration analysis are among others Fang et al. (1994), Baum et al. (1999), Kakkar (2001), Wang (2004), Villeneuve and Handa (2006), and Cuestas and Gil-Alana (2009).

This paper aims to examine the validity of long run PPP by using a fractional integration approach, using monthly Consumer Price Indices (CPI) and bilateral nominal exchange rates data between China and the U.S. from 1994.01 to 2010.11. Although there are numerous studies which test the PPP hypothesis, very few examine the case of

China—the largest transitional and developing economy. Wang (2005) and Shi (2006) applied unit root tests on China's real exchange rates over the periods 1980-2003 and 1991Q1-2005Q3 respectively, and both showed that the real exchange rates in China were nonstationary. Guo (2010) used time series and panel cointegration tests to both the official and the black market exchange rates in China over the period 1985-2006, and concluded that the real exchange rate in China is inconsistent with the long run PPP hypothesis in traded goods for both black market and official markets. Our study, however, is the first article to employ long memory or I(d) techniques to test the PPP hypothesis in China. The current study therefore enriches the existing literature by testing the PPP hypothesis in China. Moreover, ever since its economic reform and its policy of opening-up at the end of the 1970s, China has been transforming from the previous centrally planned economy to a market-oriented one. As its influence on the world economy has increased, China's 'gradualist' reform has been drawing more attention in recent economic literature, generating great interest and intense debate (Young 2000; Lau, Qian, and Roland, 2000; Brandt and Rawski, 2008; Jefferson, 2008). This study provides an empirical analysis of the extent of China's market economy, since PPP holds under the conditions of satisfying the market economy.

The remainder of the paper is as follows. The next section briefly discusses the PPP hypothesis. In Section 3, data are presented. Section 4 outlines the econometric methodology in our research and reports the empirical results. In the final section some concluding comments will be offered.

2. THE PPP HYPOTHESIS

PPP theory establishes the relationship between the nominal exchange rate and the relative prices between two countries. The idea behind the doctrine is that in the presence of international arbitrage the purchasing power of a currency in one country should be the same anywhere in the world in equilibrium. PPP hypothesis holds if the nominal exchange rate between two countries is equal to the ratio of their absolute price levels. In our study, that is:

$$NER_t^{¥/\$} = \frac{P_t^{U.S.}}{P_t^{CHA}} \quad \text{for all t,} \tag{1}$$

where $NER_t^{¥/\$}$ is the nominal exchange rate between the Chinese Yuan and the U.S. Dollar, $P_t^{U.S.}$ and P_t^{CHA} denote the price levels of the basket of goods in the U.S and China respectively. Equation (1) also implies that the real exchange rate between the two countries satisfies:

$$RER_t^{¥/\$} = \frac{NER_t^{¥/\$} P_t^{CHA}}{P_t^{U.S.}} = 1 \quad \text{for all t.} \tag{2}$$

Equations (1) and (2) are often known as the "*absolute PPP hypothesis*" since it relates the absolute levels of prices across two countries with the nominal exchange rate. In reality, absolute PPP does not hold because of many reasons (such as different consumption baskets, transaction costs, etc. (Taylor and Taylor, 2004)). Hence, it is common to use the "*relative PPP hypothesis*", which states that the rate of changes in price levels of two countries (measured in the common numeraire) should be equal, or at least, revert to equality in the long run (Obstfeld and Rogoff, 1996). This implies in our study that:

$$RER_t^{¥/\$} = \frac{NER_t^{¥/\$} P_t^{CHA}}{P_t^{U.S.}} = r \quad \text{for all t,} \tag{3}$$

where r is a constant.

This study uses equation (3), which should hold in the long run, for the purpose of empirically testing the PPP hypothesis in China.

3. DATA

The data sets examined in this paper are monthly data from 1994.01 to 2010.11, as it would make little sense to use data before 1994. Before 1994, the foreign exchange system in China was basically a planned one, and Chinese government adopted a major market-oriented foreign exchange system reform at the beginning of 1994 (Lin and Schramm, 2003). The monthly price levels, P_t^{CHA} and $P_t^{U.S.}$, are measured by the monthly CPI's of the two countries respectively. The monthly CPI data in China are obtained from the online database of National Bureau of Statistics of China, and the monthly CPI data in the U.S. are the CPI-U (Consumer Price Index-All Urban Consumers) published by the U.S. Bureau of Labor Statistics. The monthly $NER_t^{¥/\$}$ are measured in the unit of Chinese Yuan to one U.S. Dollar and are represented by the corresponding exchange rate in the first day of each month from 1994 to 2010, which we retrieve from the Board of Governors of the Federal Reserve System.

[Insert Figures 1 – 3 about here]

Figure 1 displays the time series data, i.e. the log of the real exchange rate in China with respect to the US dollar. We observe that after an increase during the first two/three years, the values decrease slowly over time until the last two years of the sample when the values become relatively stable. The correlogram and the periodogram of the data, displayed respectively in Figures 2 and 3 seem to indicate that the series is nonstationary, given the slow decrease in the sample autocorrelation values and the large peak in the periodogram at the smallest frequency.

[Insert Figures 4 – 6 about here]

First differenced data are presented in Figure 4. The series might have now an appearance of stationarity though as the correlogram (Figure 5) and periodogram (Figure 6) indicate, monthly seasonal effects are also an important feature of the data.

4. TESTING THE LONG-RUN PPP HYPOTHESIS AND RESULTS

4a Methodology

As mentioned above, we employ fractional integration to test the mean reversion of real exchange rates in China. Specifically, we define a fractionally integrated process (also called $I\,(d)$ process) as:

$$(1 - L)^{d} x_t = u_t , \qquad (4)$$

where u_t is an I(0) process, defined as a covariance stationary process with a spectral density function that is positive and bounded at the zero frequency. Thus, u_t may be a white noise process, but also a stationary and invertible ARMA process. Moreover, x_t in (4) can be the errors in a regression model of form:

$$y_t \;=\; \beta^T z_t \;+\; x_t, \qquad (5)$$

where y_t is our series of interest, i.e., the real exchange rate, β is a (kx1) vector of unknown parameters, z_t is a (kx1) vector of deterministic terms that might include, for example, an intercept (z_t= 1), or an intercept with a linear trend ($z_t = (1,t)^T$).

We will present in the empirical work estimates of d based on the frequency domain and using both parametric and semiparametric techniques. The difference between the two is that in the latter no functional form is imposed on the I(0) error term u_t. In the parametric methods we use a Whittle approximation to the likelihood function (Dahlhaus, 1989) along with a Lagrange Multiplier (LM) procedure developed by Robinson (1994). Several semiparametric methods (Robinson, 1995; Shimotsu and Phillips, 2005) will also be implemented.

Finally, it is important to note that the estimation of d is crucial to determine the existence of evidence in favour of the PPP. Thus, if the fractional differencing parameter d is found to be smaller than 1, then mean reversion occurs and PPP will be satisfied in the long run. Moreover, the smaller the value of d is, the faster the process of convergence is. On the other hand, if the estimated value of d is equal to or higher than 1, no evidence of PPP will be found.

4b. Empirical results

In this section we first consider the model given by the equations (4) and (5) with $z_t = (1, t)^T$, i.e.,

$$y_t = \alpha + \beta t + x_t; \qquad (1-L)^d x_t = u_t, \qquad t = 1, 2, ..., \qquad (6)$$

where α and β are the coefficients corresponding to an intercept and a linear time trend, and x_t are the regression errors that are supposed to be I(d) where d can be a real value. Initially, we suppose that u_t is a white noise process, though we will also consider different forms of weak autocorrelation. In particular, we try with AR(1), Bloomfield (1973), and seasonal (monthly) AR(1) disturbances. Higher AR orders were also employed and the results were substantially the same as with the AR(1) cases.[1] The model of Bloomfield (1973) is a non-parametric approach that produces autocorrelations decaying exponentially as in the AR case, and that fits extremely well in the context of the Robinson's (1994) tests employed in this section. (See, e.g., Gil-Alana, 2004)

[Insert Table 1 about here]

Table 1 displays the results of the Whittle estimates of d along with the 95% confidence intervals of the non-rejection values of d using Robinson's (1994) parametric approach, for the three standard cases examined in the literature, i.e., the case of no regressors in the undifferenced regression in (6) (i.e., α = β = 0 a priori), the case of an intercept (α unknown and β = 0 a priori), and an intercept with a linear time trend (α and

[1] Other estimation methods (Sowell, 1992, Beran, 1994) were also employed and they lead essentially the same results.

β unknown). We display the results for the four types of disturbances previously mentioned.

The first feature observed in this table is that, in all except two cases, the estimated values of d are above 1, the two exceptions being the cases of Bloomfield and monthly AR disturbances with no regressors. Nevertheless, in these two cases, the unit root null hypothesis cannot be rejected at the 5% level. Thus, according to these results, the PPP hypothesis is decisively rejected for the case of China.

We perform several specification tests to determine what the most correct specification for this series might be, and according to the t-values for the deterministic terms, and several LR tests, the model with an intercept and seasonal AR(1) disturbances seems to be the most adequate model. That is,

$$\text{Log } RER_t = \underset{(-52.74)}{-0.2593} + x_t; \quad (1 - L)^{1.286} x_t = u_t; \quad u_t = 0.576 u_{t-12} + \varepsilon_t,$$

t-values in parenthesis, implying then that the growth rate series still displays a component of long memory behavior (with an order of integration of about 0.286).

To corroborate the above results, we also implement a semiparametric approach to estimate d that is due to Robinson (1995). It is basically a "*local Whittle estimator*" in the frequency domain, considering a band of frequencies that degenerates to zero. Given its semiparametric nature, we do not impose any particular specification for the error term though the estimates will depend on a bandwidth number.

[Insert Figure 7 about here]

The estimates based on the above approach are displayed in Figure 7.[2] Along with the estimates for each bandwidth number (displayed in the horizontal axe in the figure) we also present the 95% confidence band corresponding to the I(1) hypothesis. We observe that for all bandwidth numbers, the estimates are within or above the I(1) interval, suggesting once more that the PPP hypothesis is not satisfied in this case.[3]

In the following part of the article we are concerned with the stability of the estimates of d across the sample period. This is a relevant issue noting that even though the PPP seems to be unsatisfied for the whole sample period, it may be valid for a particular subsample. Moreover, the presence of breaks in the data may produce biases in the estimation results (see Diebold and Inoue, 2001; Granger and Hyung, 2004, and others).

Here, the first thing we do is to re-estimate the fractional differencing parameter, d, for different subsamples of 60 observations each, that is, corresponding to five complete years of data, starting with the sample period [1994M1 – 1998M12], and moving then forward successively one observation at a time until the final sample period [2005M11 –

[2] Given the nonstationary nature of the series, it was first differenced prior to the estimation of d, adding then one to the estimated value.
[3] Almost identical results were obtained when using the method proposed by Phillips and Shimotsu (2005).

2010M11]. In all cases we suppose that the model of interest is an I(d) process with an intercept and seasonal AR(1) disturbances. The results in terms of the estimators of d and its corresponding 95% intervals are displayed in Figure 8.

[Insert Figure 8 about here]

We see in this figure that starting with the first five years of observations (1994M1 – 1998M12), the estimate of d is very high (1.62) and though it starts decreasing as we move forward in the sample, it remains statisticaly significantly above 1 until two years later. Since the subsample [1996M2 - 2001M1] until [2004M1 – 2008M12] the estimates are within the unit root interval, in many cases with values below unity, and finally, from the previous subsample until the final one the estimates are again statistically above 1 with values around 1.2.

[Insert Figure 9 about here]

Figure 9 displays the estimates of d using the same approach but now with subsamples of 120 observations (10 years) each. We observe here that for the first ten point estimates, corresponding to the subsamples from [1994M1-2003M12] to [1994M10-2004M9] the values of d are strictly above 1 with the unit root being rejected in favour of higher orders of integration. Then, the estimates are lower, being in many cases below 1 and the unit root null cannot be rejected for the subsamples from [1994M11-2004M10] to [2000M2-2009M1]. The last eleven estimates (from [2000M3-2009M2] to [2000M12-2010M11] present values slightly above 1 and the unit root null is again rejected. Thus, although there seems to be a slight reduction in the degree of integration of the series about the middle of the sample, mean reversion does not take place and thus, the PPP hypothesis is not satisfied.

In the final part of the manuscript we wonder what the sources for the nonstationarity and the high degree of dependence observed in the real exchange rates might be. For this purpose we estimated d for the three components that form the real exchange rates, i.e., the nominal exchange rates, and the two (US and Chinese) prices.

[Insert Figure 10 about here]

In Figure 10 we display the Whittle estimates of d for the three logged series using the semiparametric approach of Robinson (1995). The results are very conclusive. The log nominal rate presents an order of integration above 1 for all bandwidth numbers; the log of China CPI also displays values which are above 1 in the majority of the cases; the log US CPI is only the one that presents values of d below 1 in some cases.[4] Choosing the bandwidth number $m = (T)^{0.5} \approx 14$, the estimates of d for the log-nominal exchange rates, and logged Chinese and US prices are respectively 1.414, 1.500 and 0.783, implying that the unit root null (i.e., $d = 1$) is rejected in the first two cases at the 5% level. For the US CPI, the null of a unit root cannot be rejected at the 5% but is rejected in favour of mean reversion ($d < 1$) at the 1% significance level. Therefore, it may be

[4] The issue of the optimal bandwidth selection in semiparametric frequency domain methods is still unresolved. It clearly deals with the classical trade-off bias/asymptotic variance depending on the choice of the bandwidth number. Some authors propose the use of $m = (T)^{0.5}$.

concluded that it is the Chinese economy that should make major changes in order for PPP to be satisfied.

4c. Discussion

The test statistics reported above generally show that the long run PPP hypothesis in China does not hold. This result is consistent with previous studies in the real exchange rates in China (Zhang, 2002; Wang, 2005; Shi, 2006; Guo, 2010). One main reason may be that the exchange system in China after 1994 still largely depends on the control of government, although much progress has been made (Lin and Schramm, 2003). Government intervention in the exchange system can distort PPP and result in the violation of the PPP hypothesis (Choudhry, McNown and Wallace, 1991).

When we look at the recursive estimates of d using sample periods of five and ten complete years (Figures 8 and 9), we first notice a structural change at the beginning of the period investigated, which is in accordance with the fact that China's exchange rate regime was reformed from the previous centrally planned one to the market-oriented one. After the change in 1994 (McKinnon and Schnabl, 2009), the recursive estimates of d do not change much, especially when we consider longer sample periods (10 complete years, in Figure 9). So it may be concluded that China's exchange rate system has not changed much, even after the Chinese exchange rate system reform on 21 July 2005, which confirms the results obtained in other previous studies such as Goldstein and Lardy (2006) and Ogawa and Sakane (2006).

5. CONCLUSIONS

For the purpose of enriching the empirical literature in testing the PPP hypothesis, we have employed fractional integration techniques to test the PPP hypothesis in the US/China relationship over the sample period 1994M01 to 2010M11. Our empirical results show that there is no mean reversion for the real exchange rate between China and U.S. across the whole sample period, which is incompatible with the PPP hypothesis but consistent with previous studies. We also investigated the stability of the estimated fractional differencing parameter d over different subsample periods with 5-year and 10-year data frequencies respectively, and find that after the structural change at the beginning of the sample period, the recursively estimated parameter d is stable and generally over 1. This dynamic result may lead us to the conclusion that after the structural reform in 1994, China's exchange rate system remained stable, even after the announced exchange system reform in 2005.

China's huge trade surpluses and continuing rapid accumulation of foreign exchange reserves have led to the recent debate about China's exchange rate system and policy (McKinnon, 2006; McKinnon and Schnabl, 2009; Goldstein and Lardy, 2008). Our study contributes to the literature in this debate. Since the PPP hypothesis in China does not hold in the long run, it appears that the estimate of the equilibrium exchange rate of Renminbi is less reliable with the PPP approach. The government therefore should be cautious about using the PPP hypothesis to analyze the relevant issues of Renminbi.

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Figure 1: Log of the Real Exchange rate

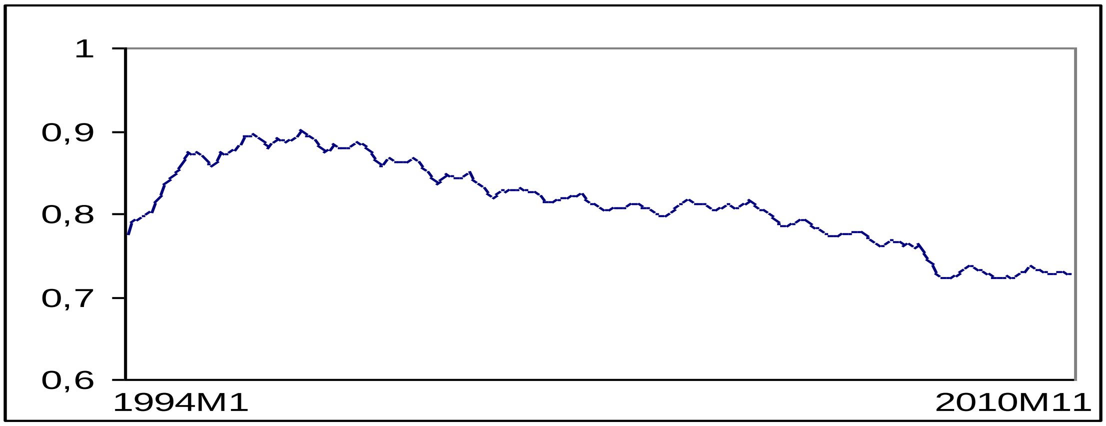
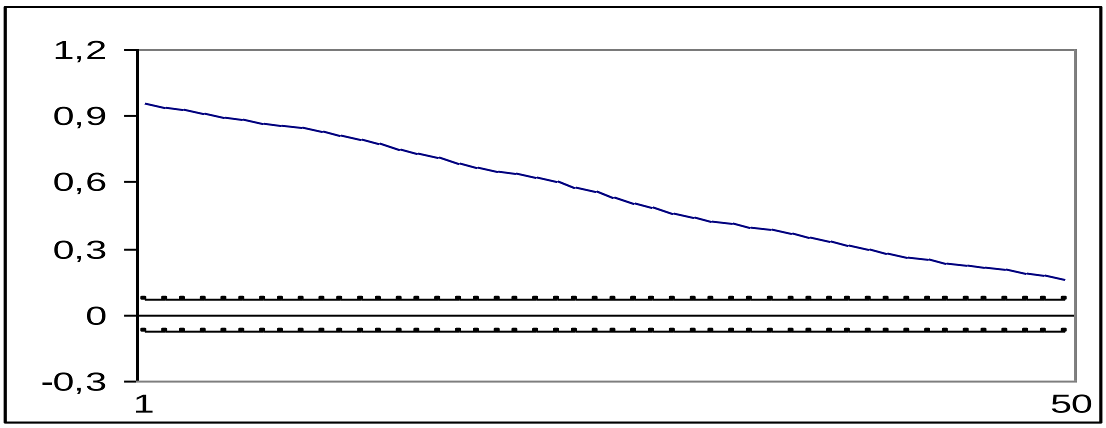
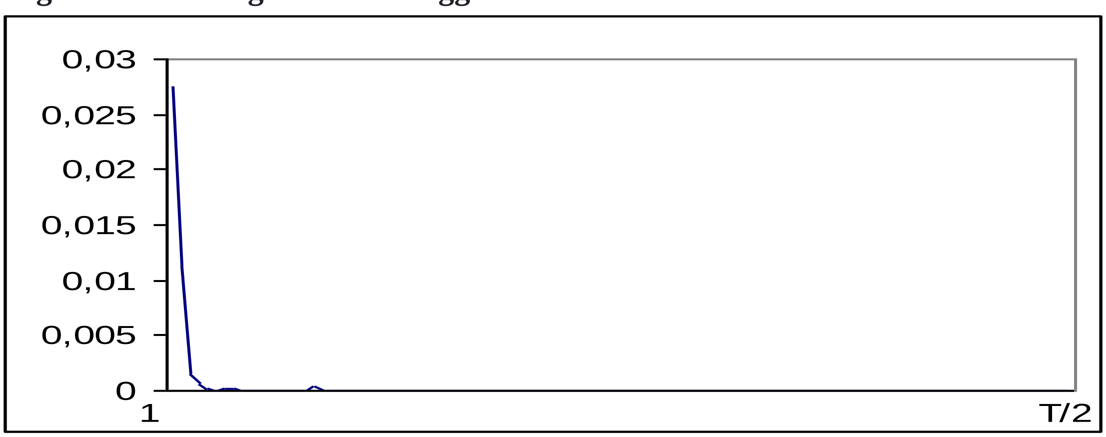


Figure 2: Correlogram of the logged data



The thick lines refer to the 95% confidence band for the null hypothesis of no autocorrelation.

Figure 3: Periodogram of the logged data



The periodogram refers to the discrete Fourier frequencies $\lambda_j = 2\pi j/T$, $j = 1, \ldots, T/2$.

Figure 4: First differences of the logged data

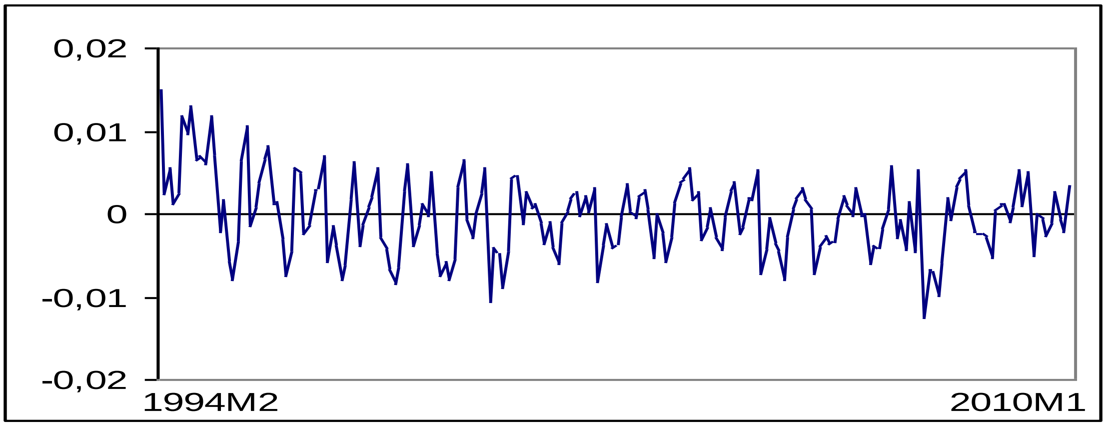
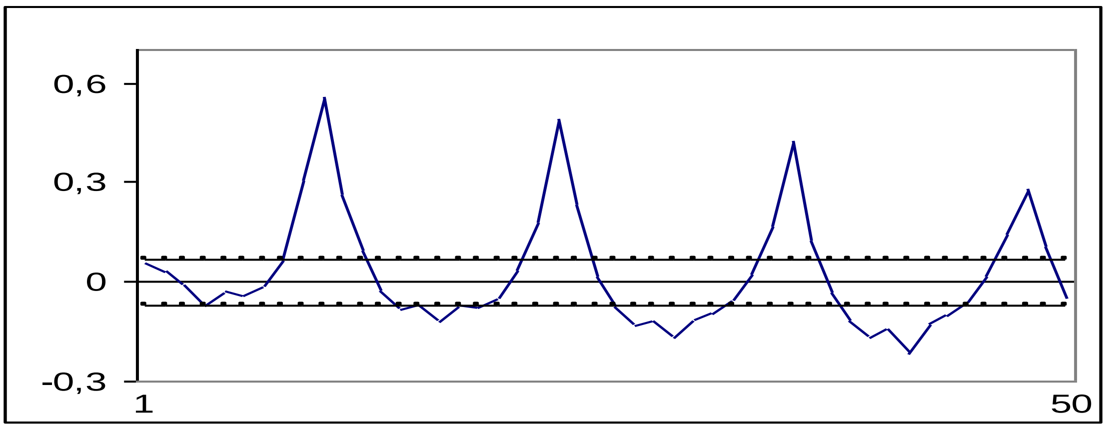
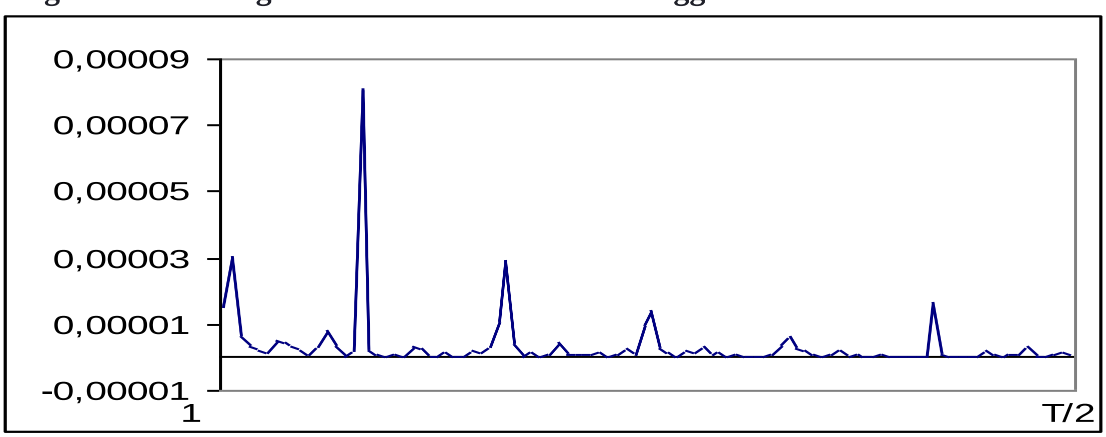


Figure 5: Correlogram of the first differenced logged data



The thick lines refer to the 95% confidence band for the null hypothesis of no autocorrelation.

Figure 6: Periodogram of the first differenced logged data



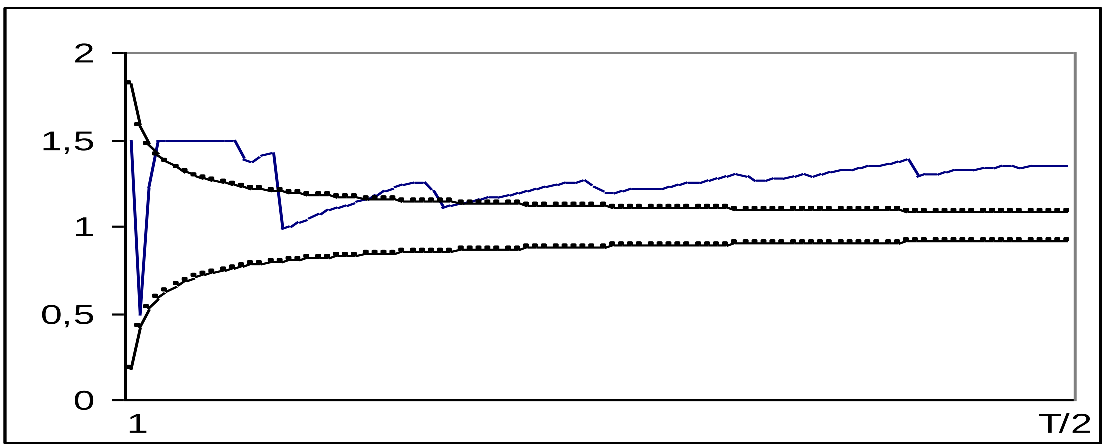
The periodogram refers to the discrete Fourier frequencies $\lambda_j = 2\pi j/T$, j = 1, …, T/2.

Table 1: Estimates of d based on the parametric method of Robinson (1994)

	No regressors	An intercept	A linear trend
White noise	1.011 (0.931, 1.117)	1.357 (1.239, 1.524)	1.342 (1.234, 1.496)
AR(1)	1.395 (1.254, 1.593)	1.044 (0.884, 1.266)	1.045 (0.894, 1.251)
Bloomfield (1)	0.991 (0.854, 1.171)	1.122 (1.004, 1.303)	1.122 (1.009, 1.297)
Monthly AR(1)	0.997 (0.899, 1.114)	**1.286** **(1.190, 1.417)**	1.275 (1.187, 1.382)

The values are Whittle estimates of d in the frequency domain. The values in parenthesis refer to the 95% confidence intervals of non-rejection values of d using Robinson's (1994) tests. In bold the selected specification.

Figure 7: Whittle semiparametric estimates of d (Robinson, 1995)



The horizontal axis refers to the bandwidth parameter, while the vertical one reports the estimated value of d. The confidence band refers to the I(1) hypothesis.

Figure 8: Recursive estimates of d using sample periods of 5 complete years

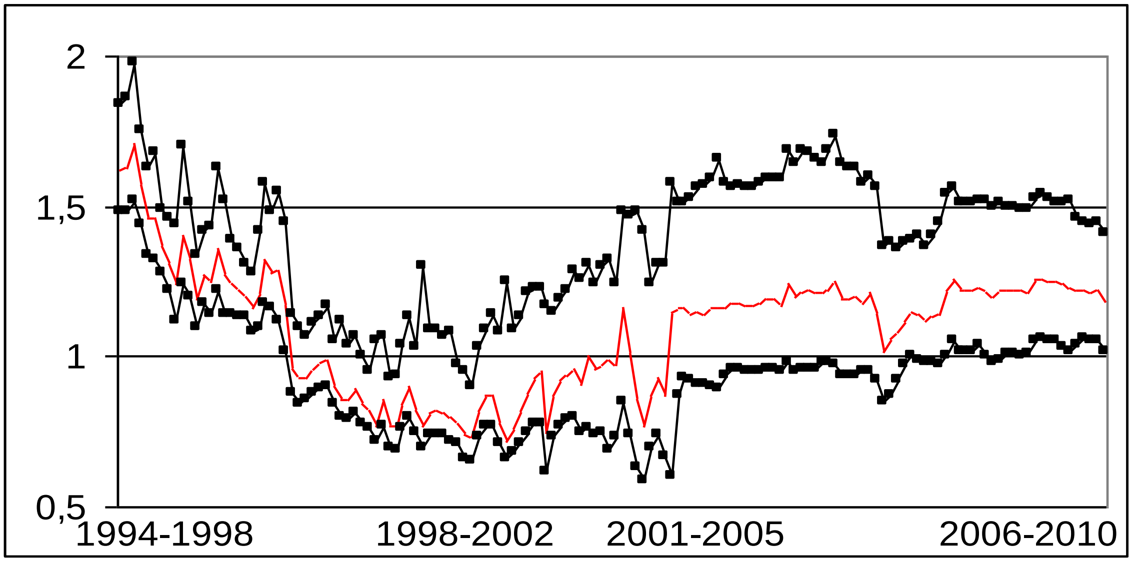


Figure 9: Recursive estimates of d using sample periods of 10 complete years

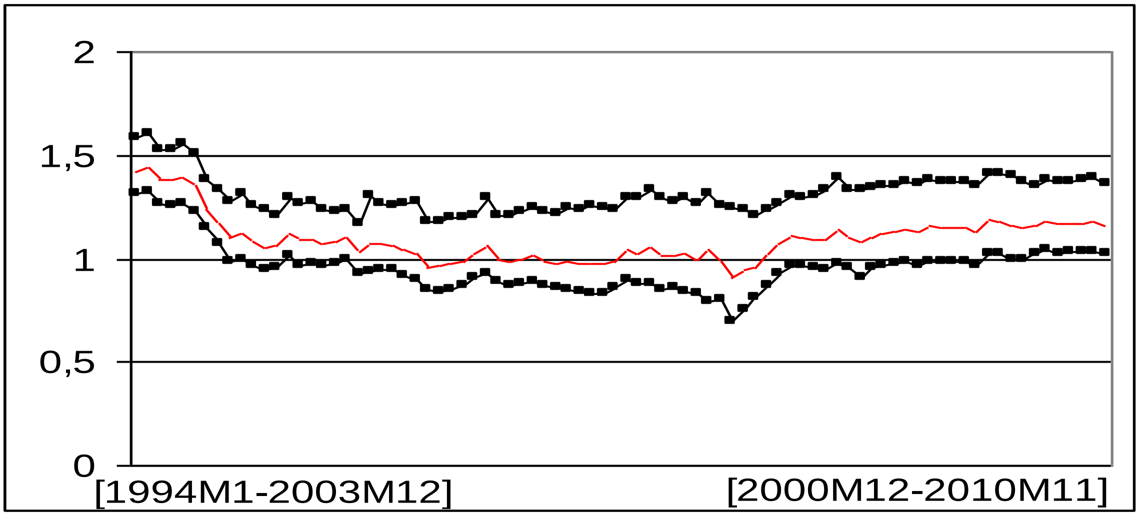


Figure 10: Estimates of d for the log nominal exchange rates and log prices