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FRACTIONAL INTEGRATION IN THE PURCHASING POWER PARITY

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ABSTRACT

The empirical evidence of the Purchasing Power Parity (PPP) hypothesis in the exchange rate market is examined by means of fractional integration analysis. Robinson's (1994) fractionally-based tests for testing unit roots and other nonstationary and stationary hypotheses are applied to nominal and real exchange rates data between U.S. and five industrialized countries. The conclusions vary substantially across the countries and across the different specifications of the disturbances and thus, it is important to specify carefully the short-run dynamics of each of the series in order to check if the PPP hypothesis holds.

Keywords: Fractional integration; Purchasing power parity.

JEL Classification: C22

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1. Introduction

The doctrine of the Purchasing Power Parity (PPP) plays an important role in the theory of trade and international economics. Underlying this interest are several factors bearing implications for theoretical models of exchange rate determination, (eg. Dornbusch (1976) and Krugman and Obstfeld (1994)), and also for practical policy deliberations, like the determination of target zones or currency re-evaluations.

The idea of PPP suggests that currencies are valued by the goods they can buy and, in equilibrium, a given basket of goods should cost the same at home and abroad in the presence of international arbitrage. It is well known, however, that strict parity obtains only under very strict conditions. Several facts, like transaction costs, trade restrictions, exchange market intervention and taxation may interfere with the PPP hypothesis and thus, it is not surprising that most empirical tests have failed to accept this theory as a short run proposition (Officer (1976), Kravis and Lipsey (1978), Artus (1978), and Frenkel (1981)).

Although almost universal agreement exists that PPP does not provide a good description of short-term exchange rates movements, no definite evidence has been found as to whether PPP holds in the long run. For example, Adler and Lehmann (1983), Darby (1983) and Roll (1979) found that deviations from PPP follow closely a random walk, suggesting that shocks have a completely permanent effect on the levels. Similarly, Baillie and Selover (1987), Corbae and Ouliaris (1988), Taylor (1988) and Mark (1990) amongst others, failed to find cointegration between nominal exchange rates and relative prices, implying that the two series tend to drift apart without bound. On the other hand, Abuaf and Jorion (1990) reported evidence supporting of PPP reversion for the 1900-72 period using multivariate unit root tests with wholesale price indexes (WPIs). Kim (1990) examined the same dataset and also found favourable evidence for long run PPP using cointegration analysis, however, using consumer price indexes (CPIs) little support was found. He argued that CPIs are more contaminated by non-traded goods than WPIs which put more weight on traded goods. Using a multivariate cointegration framework, In and Sugema (!995) and Strauss (1996) also found evidence for long-run PPP.

Most of these previous studies adopt cointegration tests, which are appropriately designed to test long-run relationships between time series, which can then be formulated as error correction mechanisms to represent the short-run dynamics underlying the long-term common trend. However, standard tests of cointegration might be too restrictive to permit acceptance or rejection of PPP as a long-run condition. In standard cointegration analysis, the individual series must be integrated of order 1, I(1), while the estimated residuals should be stationary and in particular I(0) processes, in the sense that the spectrum must be bounded and bounded away from zero at all frequencies.

The work on fractional differencing suggest that many macroeconomic time series might be modelled as I(d) processes where d can be a real number (see, eg. Diebold and Rudebusch (1989), Sowell (1992), Gil-Alaña and Robinson (1997a), etc.). A series is said to be I(d) if it becomes I(0) after applying the difference operator $(1\text{-}L)^d$, which can be defined in terms of its binomial expansion as

$$(1 - L)^d = \sum_{j=0}^{\infty} (-1)^j \binom{d}{j} L^j = 1 - dL + \frac{d(d-1)}{2!} L^2 - \dots .$$

This type of processes belongs to the class of long-memory processes, so-named for their ability to display significant dependence between observations widely separated in time, as opposed to I(0) or short-memory processes, where autocorrelations decay fairly rapid. In fact, under standard I(0) stationary ARMA processes, autocorrelations decay exponentially:

$$\rho_j \sim \kappa^j, \qquad 0 < \kappa < 1,$$

while in I(d) processes with $0 < d < 1/2$, the decayment is hyperbolic:

$$\rho_j \sim j^{2d-1},$$

where '~' means that the ratio between the left hand side and the right hand side tends to 1 as $j \rightarrow \infty$.

The distinction between I(d) processes with different values of d is important from an economic point of view: If d belongs to the interval (0,1/2), the process is stationary and mean-reverting; if d belongs to [1/2,1) is nonstationary but still mean reverting, while $d \geq 1$ means nonstationary and non-mean reverting. Thus, allowing fractional differencing, we can study a wide range of mean reversion behaviours. Examples of fractional differencing models in the exchange rate market are Diebold et al. (1991), Cheung and Lai (1993) and Masih and Masih (1995) among others.

In this paper we present some results concerning fractional differencing in the exchange rate market, using Robinson's (1994) univariate tests. These tests are described in Section 2. Section 3 applies the tests to historical annual data of prices and exchange rates between U.S. and five industrialized countries, for the 1914-1989 period, using the same dataset as in Cheung and Lai (1993). Section 4 contains some concluding remarks. A diskette containing the FORTRAN code for the tests is available from the author on request.

2. Tests of fractional integration

Robinson (1994) proposes a very general testing procedure for testing unit roots and other hypotheses in raw time series. Unlike most of unit roots tests, embedded in autoregressive (AR) alternatives, Robinson's (1994) tests are nested in a fractionally integrated model

$$(1 - L)^{d+\theta} x_t = u_t, \qquad t = 1,2,..., \tag{1}$$

$$x_t = 0, \qquad t \leq 0 \tag{2}$$

where d is a given real number, u_t is an I(0) process with parametric spectral density f, which is a given function of frequency λ and of unknown parameters, specifically

$$f(\lambda;\sigma^2;\tau) = \frac{\sigma^2}{2\pi} g(\lambda;\tau), \qquad -\pi < \lambda \leq \pi,$$

where the scalar σ^2 and the (qx1) vector τ are unknown but g is of known form, and x_t are the errors in the regression model

$$y_t = \beta' z_t + x_t, \qquad t = 1,2,....., \tag{3}$$

where $\beta = (\beta_1,\beta_2,...\beta_k)'$ is a vector of unknown parameters, z_t is a (kx1) vector of deterministic variables that might include an intercept or a time trend for example, and y_t is the time series that we observe from t=1,...n. Thus, under the null hypothesis

$$\mathbf{H_o: \theta = 0,} \tag{4}$$

x_t in (1) is I(d), and if d=1 contains a unit root at the zero frequency. Under (4), the residuals are

$$\tilde{u}_t = (1 - L)^d y_t - \tilde{\beta}'(1 - L)^d z_t,$$

where

$$\tilde{\beta} = \left(\sum_{t=1}^{n} w_t w_t'\right) \sum_{t=1}^{n} w_t (1 - L)^d y_t, \qquad w_t = (1 - L)^d z_t.$$

Unless g is a completely known function (e.g. $g \equiv 1$, as when u_t is white noise) we have to estimate the nuisance parameter τ, for example by

$$\hat{\tau} = \arg\min_{\tau \in T} \sigma^2(\tau),$$

where T is a suitable subset of R^q and

$$\sigma^2(\tau) = \frac{2\pi}{n} \sum_{j=1}^{n-1} g(\lambda_j;\tau)^{-1} I(\lambda_j),$$

where

$$I(\lambda) = |(2\pi n)^{-1/2} \sum_{t=1}^{n} \tilde{u}_t e^{it\lambda}|^2, \qquad \lambda_j = \frac{2\pi j}{n}.$$

The test statistic, which is derived from the Lagrange multiplier (LM) principle is:

$$\hat{r} = \frac{n^{1/2}}{\hat{\sigma}^2} \hat{A}^{-1/2} \hat{a}, \tag{5}$$

where

$$\hat{a} = \frac{-2\pi}{n} \sum_{j=1}^{n-1} \psi(\lambda_j) g(\lambda_j;\hat{\tau})^{-1} I(\lambda_j),$$

$$\hat{A} = \frac{2}{n} \left(\sum_{j=1}^{n-1} \psi(\lambda_j)^2 - \sum_{j=1}^{n-1} \psi(\lambda_j) \hat{\epsilon}(\lambda_j)' \left(\sum_{j=1}^{n-1} \hat{\epsilon}(\lambda_j) \hat{\epsilon}(\lambda_j)' \right)^{-1} \sum_{j=1}^{n-1} \hat{\epsilon}(\lambda_j) \psi(\lambda_j) \right),$$

$$\psi(\lambda_j) = \log\left|2 \sin\frac{\lambda_j}{2}\right|, \qquad \hat{\epsilon}(\lambda_j) = \frac{\partial}{\partial \tau} \log g(\lambda_j;\hat{\tau}).$$

Robinson (1994) established under regularity conditions that

$$\hat{r} \to_d N(0,1), \qquad as \quad n \to \infty \tag{6}$$

and thus, an approximate one-sided $100\alpha\%$ test of (4) against the alternative $\theta < 0$ rejects H_o if $\hat{r} > z_\alpha$, where the probability that a standard normal variate exceeds z_α is α. Conversely, a test of (4) against $\theta < 0$ rejects H_o if $\hat{r} < -z_\alpha$. He also showed that the tests are efficient in the Pitman sense, that when directed against local alternatives

$$H_a: \ \theta = \delta n^{-1/2} \qquad for \quad \delta \neq 0,$$

the limit distribution is Normal with variance 1 and mean which cannot (when u_t is Gaussian) be exceeded in absolute value by that of any rival regular statistic. Thus, we are under standard situations, unlike most of tests for unit roots where a nonstandard null limit distribution and lack of efficiency theory is obtained. Furthermore, the null N(0,1) distribution holds across a wide range of null hypothesized values of d, and across a broad class of exogenous regressors z_t, including $z_t \equiv 1$ and $z_t = (1,t)'$ in cases of an intercept and a linear trend respectively.

The tests of Robinson (1994) were applied to non-seasonal and seasonal data by Gil-Alaña and Robinson (1997a,b) respectively. In this article they are applied to prices and nominal and real exchange rates in order to examine if the PPP hypothesis holds.

3. Empirical application

The PPP relationship can be written as

$$sp_t = \alpha_0 + \alpha_1 p_t + \epsilon_t, \qquad (7)$$

where sp_t is the foreign price index converted to domestic currency units; p_t is the domestic price index, and α_0 and α_1 are coefficients to be estimated, in which case ε_t is an error term capturing deviations from PPP. All variables are in logs. A similar PPP specification can be found in Frenkel (1981). However, we can impose a priori the homogeneity condition $\alpha_0 = 0$ and $\alpha_1 = 1$, in which case ε_t is the nominal exchange rate (n_t) between the domestic and the foreign country.[1] In both cases, a necessary condition for PPP to hold in the long run is that ε_t is a mean-reverting process; that is, the effect of a shock to the PPP relationship will die out. In general, the PPP hypothesis can be tested whether the homogeneity condition holds or not.

The data examined in this article are annual data for the period 1914-1989 taken from Cheung and Lai (1993). The price levels p_t and sp_t are measured in CPI's, and we examine five bilateral intercountry relations between the U.S. as the home country and Canada, U.K., Japan, France and Italy as the foreign countries.

We employ throughout the model (1) - (3), with $z_t = (1,t)'$, $t \geq 1$, $z_t =$

[1] SP_t is constructed by multiplying price indexes (P_t) by the corresponding nominal exchange rates (N_t). Thus, taking logs, $sp_t = p_t + n_t$, and substituting this expression in (7) with the homogeneity condition implies that $n_t = \varepsilon_t$.

(0,0)' otherwise, testing (4) for different hypothesized values of d, from 0 through 2.25 with 0.25 increments, studying separately the cases of $\beta_i \equiv 0$ a priori (i.e., with no regressors); β_1 unknown and $\beta_2 = 0$ a priori, (i.e., with an intercept) and finally, β_1 and β_2 unknown (i.e., with a time trend), modelling the I(0) disturbances as white noise and non-seasonal and seasonal AR processes of orders 1 and 2.

We report in this article the results of $\hat{r}$ in (5) for the univariate price series p_t and sp_t (in Tables 1-5), for the nominal exchange rates, $n_t = sp_t - p_t$ (in Tables 6-10), and finally for the real exchange rates (in Tables 10-15). Given that $\hat{r}$ is a one-sided test statistic, we should expect a monotonic decrease in $\hat{r}$ with respect to d. Thus for example, if we reject H_o (4) against the alternative $\theta > 0$ for $d = 0.75$, an even more significant result in this direction should be expected when testing H_o for $d = 0.5$. However, in the event of misspecification, this property is not necessarily to be expected: frequently misspecification inflates both numerator and denominator of $\hat{r}$, to varying degrees, and thus affects $\hat{r}$ in a complicated way. We only report across the tables the results for those cases where monotonicity was achieved, and indicate by "--" the values where we observe lack of this property, which in most cases occur when u_t is autocorrelated. This is not surprising given the wide range of null hypothesized values of d, and the delicacy in confounding fractional differencing with autoregressions. For example, if we think that a plausible model for y_t is

$$(1 - L)y_t = u_t; \quad u_t = \tau u_{t-1} + \epsilon_t, \qquad t = 1,2,...,$$

with white noise ε_t and τ close to 0, a very similar model, though with very different statistical properties might be

$$y_t = u_t; \quad u_t = \bar{\tau} u_{t-1} + \epsilon_t, \qquad t = 1,2,...,$$

with $\bar{\tau}$ close to 1, and thus, we could expect not to reject H_o (4) in (1)-(3) with $\beta_i \equiv 0$ and AR(1) u_t, either when $d = 0$, (in which case the estimated AR coefficient should be arbitrarily close to 1), or when $d = 1$, (with the estimated AR coefficient arbitrarily close to 0), but reject H_o perhaps for values of d ranging between these two values.

We firstly look at the individual price series in order to investigate what the proper integration order of these series might be. Starting with the domestic prices in Canada (in the upper part of Table 1), we observe that if u_t is white noise and we do not include regressors, the only non-rejection case corresponds to the unit root null hypothesis (i.e., $d=1$). However, including an intercept or a time trend, still with white noise u_t, the unit root null is rejected and the non-rejections are now d = 1.50 and 1.75. Allowing u_t to be parametrically autocorrelated, we report results for cases of non-seasonal and seasonal AR(1) and AR(2) processes. The tests were also performed allowing higher order autoregressions, obtaining similar results. With non-seasonal ARs, the unit root null is never rejected when including regressors, though greater integration orders also are plausible in some cases. We observe that if u_t is AR(1) and we include a time trend, H_o is not rejected when d = 0.5 and d = 0.75, but in these cases the estimates of the AR coefficients are close to 1 in both cases[2]. When u_t follows a seasonal AR process, results are similar to those with white noise u_t: the unit root null is not rejected when we do not include regressors, but it is rejected in favour of more nonstationarities (with d > 1) when including an intercept or a time trend.

In the lower part of Table 1 we present results for foreign prices in Canada. They are similar to those obtained in the previous part of the table, referred to domestic prices. Thus, the unit root null is not rejected for white noise and seasonal AR u_t if $\beta_i \equiv 0$ a priori, and for non-seasonal AR u_t if we include regressors in the model, however, including an intercept or a time trend, with white noise or seasonal AR u_t, this hypothesis is rejected in favour of alternatives with d > 1.

(Tables 1 and 2 about here)

Results for the U.K. case are given in Table 2. They do not differ much from those in Table 1. If u_t is white noise or a seasonal AR process, the unit root null is not rejected if we do not include regressors either in the domestic or in the foreign prices, but including an intercept or a time trend, this hypothesis is always rejected, and the non-rejection values of d are now 1.75 and 2 for p_t, and 1.25 and 1.50 for sp_t. Allowing non-seasonal ARs, d = 1 is not rejected when including regressors, though other possibilities with d slightly greater or smaller than 1 are also plausible.

In Table 3 we report results for the Japanese case. A striking fact is observed here. Looking at the domestic prices, the unit root null hypothesis is always rejected, and the non-rejection values always take place when d is greater than one, ranging in all cases between

[2] Though it is not reported in the table, these estimates are 0.91 and 0.80 when d = 0.50 and 0.75 respectively.

(Table 3 about here)

1.50 and 2. If we concentrate on the foreign prices, however, the unit root is never rejected independently of the inclusion or not of deterministic variables and the way of modelling the disturbances. Thus we observe a higher integration order for the domestic prices than for the foreign ones, with the former prices increasing at a higher rate. This might be one of the reasons why Cheung and Lai (1993) failed to find cointegration in this country when testing with the augmented Dickey-Fuller (see Dickey and Fuller (1979)) and the likelihood ratio tests of Johansen (1991).

Similarly for France (in Table 4), the unit root null is always rejected for the domestic prices, with the non-rejection values of d ranging between 1.25 and 1.75 when u_t is white noise or a seasonal AR, and ranging between 1.25 and 2 with non-seasonal AR u_t. On the other hand, when looking at the foreign prices, if d = 1, H_o is never rejected, along with other possibilities with d slightly greater or smaller than 1.

(Tables 4 and 5 about here)

Table 5 reports results for Italy. The unit root null is not rejected for p_t if u_t is AR(1), but for the remaining specifications of u_t, d = 1 is always rejected in favour of alternatives with d greater than 1, ranging in all cases between 1.25 and 1.75. Looking at the lower part of the table, we see that for the foreign prices, the unit root is not rejected if u_t is white noise or a seasonal AR process, however if u_t is a non-seasonal AR, the non-rejection values of d are greater than 1 when including no regressors, but smaller than 1 when including an intercept or a time trend.

As a conclusion, we can summarize the results on the univariate price series by saying that the domestic and foreign price series in Canada and U.K. are integrated of order 1 if the disturbances are non-seasonal ARs. If they follow a white noise or a seasonal AR process, the I(1) null hypothesis is not rejected when including no regressors, but greater integration orders are observed when allowing an intercept or a time trend. The domestic prices in Japan, France and Italy are all integrated with orders greater than 1, with the non-rejection values of d ranging between 1.50 and 2 in Japan, and between 1.25 and 2 for France and Italy, though in the latter country, if u_t is AR(1), the unit root null is not rejected. When looking at the foreign prices, the unit root hypothesis is not rejected in these three countries, indicating that the domestic prices grow at a higher rate than the foreign ones.

Testing for a unit root in the individual price series is a preliminary step when testing the PPP hypothesis with cointegration techniques. However, given that we reject the unit root null in the domestic prices in three out of five countries studied, we have decided to follow an alternative approach, testing the PPP by looking directly at the integration order in the nominal and real exchange rates data.

In Tables 6-10 we again look at $\hat{r}$ in (5) but y_t is now the nominal exchange rate of each country. As mentioned before, to check the integration order of each of these series is important since it can tell us something about the mean reversion properties of the series: Thus, if $d \geq 1$ shocks will have permanent effects on the levels, while $d < 1$ will imply mean reversion behaviour, with shocks dying away in the long run.

In Table 6 we look at the nominal exchange rate in Canada. We observe that the results are similar for the different specifications in (3), with all non-rejections occurring at the same values of d independently of the inclusion or not of an intercept and a time trend. However, the results vary substantially depending on how we model the I(0) disturbances. Thus, if u_t is white noise, the non-rejection values of d are 1 and 1.25; if u_t is AR(1) they are 0.25 and 0.50; if u_t is AR(2), d ranges between 0.50 and 1.25, and finally if u_t is a seasonal AR process, the non-rejection d's are 1 and 1.25. Thus, the mean reversion behaviour is only observed if u_t follows a non-seasonal AR process.

(Tables 6 and 7 about here)

Table 7 reports the results for the U.K. As with the Canadian data, the non-rejection values of d are 1 and 1.25 if u_t is white noise or a seasonal AR process, and also d = 0.75 is not rejected in this series when including a time trend. Allowing non-seasonal AR u_t, the non-rejection values of d are greater than 1 if we do not include regressors but smaller (and thus showing mean-reversion) if we include an intercept or a time trend.

Results for the Japanese case are given in Table 8. They are again similar for cases of white noise and seasonal AR u_t, but the non-rejection values of d range now between 1.50 and 2, finding therefore conclusive evidence against the PPP hypothesis. If u_t is a non-seasonal AR, the null is not rejected when d = 1, and taking any other hypothesized value of d, H_o is always rejected. Thus, we find in this table conclusive evidence against mean-reverting behaviours.

(Tables 8 and 9 about here)

In Table 9 we report the results for France. If u_t is white noise or a seasonal AR, the non-rejections are 1 and 1.25, and for any other hypothesized value of d, H_o is always rejected. If u_t is AR(1), the non-rejection values of d range between 1 and 1.50, and the only cases consistent with mean-reversion occur when u_t is AR(2) and we include a time trend, with the non-rejection d's ranging then between 0.25 and 0.75.

Finally in Table 10, we report the results for Italy. If u_t is white noise, d = 1 is always rejected in favour of more nonstationary alternatives, and the non-rejection values are 1.25 and 1.50. If u_t is a seasonal AR process, the non-

(Table 10 about here)

rejection values of d are slightly smaller, 1 and 1.25, and finally, if u_t is a non-seasonal AR process, all non-rejections occur for values of d greater than 1. Thus, we also find in this series conclusive evidence against mean-reversion behaviour.

We can conclude the analysis of these series by saying that the mean-reversion behaviour in the nominal exchange rate is only observed for Canada and U.K. when we model the I(0) disturbances as non-seasonal ARs. Modelling u_t as white noise or seasonal ARs, the integration orders are equal to or greater than 1 in practically all cases. For France, mean reversion is observed if we include a time trend in the model and the disturbances are AR(2) with d = 0.25 and 0.50. In all the other situations, the non-rejection values of d are always greater than 1 as is the case with the Japanese and the Italian data.

The strong evidence against mean-reverting behaviour observed in all these series when we model u_t as white noise or as a seasonal AR process is not surprising if we note that nominal rates do not take into account about price differentials. A more realistic version of the PPP hypothesis should concentrate on real rather than nominal exchange rates, and thus, in order to complete the analysis, we also report, in Tables 11-15, the results on the real exchange rates.

Table 11 gives the results for the real exchange rate in Canada. The non-rejection values of d are 1 and 1.25 when u_t is white noise, and range between 0.75 and 1.25 when u_t is a seasonal AR. Supposing u_t follows a non-seasonal AR process, the non-rejection values of d are 0.25 and 0.50 if u_t is AR(1), and range between 0.50 and 1.25 if u_t is AR(2). Comparing these results with those in Table 6 referred to the nominal rates, we observe that they are rather similar, with a slightly smaller degree of integration when u_t follows seasonal ARs.

(Tables 11 and 12 about here)

Similarly for U.K., in Table 12, we see that if u_t is white noise or a seasonal AR process, H_o is not rejected for d = 1 and 1.25, but allowing non-seasonal AR u_t, the non-rejection values of d range between 0 and 0.50 when we include an intercept or a time trend, and therefore, suggesting a certain evidence of mean reversion, with shocks dying away in the long run.

Results for Japan are given in Table 13. The non-rejection values of d are now 0.75 and 1 for white noise and seasonal AR u_t, and range between 0 and 0.75 for non-seasonal AR. These results are in sharp contrast with those obtained in Table 8 referred to nominal rates, where the null hypothesis was always rejected when d was smaller than 1.

(Tables 13, 14 and 15 about here)

Similar results are obtained in Tables 14 and 15 when looking at the real exchange rates in France and Italy respectively. In both tables we see that if u_t is white noise or a seasonal AR process, the null is not rejected when d = 0.75 or 1. Modelling u_t as AR(1), H_o is not rejected when d ranges between 0.75 and 1.25 in France, and when d = 0 in Italy, and finally, modelling u_t as an AR(2) process, the null was always rejected in both countries.

These results suggest that the integration orders are smaller in the real than in the nominal exchange rates, which is not surprising given the effect of price differentials on the series. We observe evidence of fractional differencing, with possible mean-reverting behaviour in all countries. If u_t is white noise or a seasonal AR process, these integration orders range between 0.75 and 1.25, and allowing u_t to be non-seasonal AR, this integration order varies substantially depending on the country: it ranges between 0.75 and 1.25 for France; between 0 and 0.75 for Japan; it is 0.25 or 0.50 for Canada and U.K., and d = 0 is the only non-rejection value for Italy.

4. Conclusions

The conclusions after applying the tests of Robinson (1994) on the domestic and foreign prices and in the nominal and real exchange rates of five industrialized countries in relation to the U.S. dollar can be summarized as follows.

When looking at the individual price series, the results in Canada and U.K. suggest that both, domestic and foreign prices are I(1) when u_t is AR. If u_t is white noise or a seasonal AR, the I(1) null hypothesis is also non-rejected when modelling with no regressors, but greater integration orders are observed if we include an intercept or a time trend. Foreign prices in Japan, France and Italy might also be I(1) but this hypothesis is strongly rejected for the domestic prices in these three countries.

Looking at the nominal exchange rates, mean reversion is observed in Canada and U.K. when the disturbances are modelled with non-seasonal ARs. However, if u_t follows a white noise or a seasonal AR process, H_o is always rejected when d is smaller than one. Results for France indicate that mean reversion only appears if we include a time trend and u_t is AR(2), while in Japan and Italy, the shocks seems to persist forever.

When looking at the PPP hypothesis through the real exchange rates, we observe that mean reversion might occur in all countries when u_t is modelled as a non-seasonal AR process, with the order of integration varying substantially across the countries. Thus, we can conclude by saying that the real exchange rates might be fractionally integrated, with integration orders smaller than one, implying that shocks will tend to disappear in the long run.

However, the results show that the integration orders of the series can vary substantially depending on how we model the I(0) disturbances. Thus, it might be important to specify carefully the short run dynamics of the series in order to check if the PPP hypothesis holds. In view of the preceding remark, an alternative approach when modelling these series might be to estimate simultaneously the long and short run parameters of ARFIMA models by some maximum likelihood methods, choosing the model whose residuals are the closest to white noise. Semiparametric and non-parametric methods for estimating d first may be another alternative approach.

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TABLE 1

$\hat{r}$ in (5) for domestic prices in Canada*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	15.47	14.47	7.92	3.27	-0.14'	-2.12	-3.17	-3.76	-4.11	-4.36
with an intercept	15.47	13.87	11.94	11.06	6.94	2.73	0.24'	-1.24'	-2.21	-2.88
with a time trend	18.02	17.29	15.34	11.77	7.10	2.94	0.23'	-1.34'	-2.26	-2.87
for AR(1) u_t:										
with no regressors	--	--	--	--	--	1.20'	-0.63'	-1.81	-2.59	-3.13
with an intercept	--	--	--	--	-0.41'	-1.37'	-2.05	-2.50	-2.89	-3.26
with a time trend	4.09	3.53	1.21'	0.11'	-0.18'	-1.00'	-1.86	-2.54	-2.95	-3.23
for AR(2) u_t:										
with no regressors	--	--	--	--	--	3.43	1.29'	0.08'	-0.39'	-2.01
with an intercept	--	--	--	--	-0.23'	-0.62'	-1.19'	-1.47'	-1.69	-1.81
with a time trend	--	--	--	--	0.01'	-0.17'	-0.80'	-1.36'	-1.67	-1.78
for seasonal AR(1) u_t:										
with no regressors	6.71	5.13	2.20	0.63'	-0.54'	-2.12	-3.22	-3.80	-4.15	-4.39
with an intercept	7.71	7.33	6.47	6.44	6.36	3.34	0.42'	-1.34'	-2.36	-2.99
with a time trend	10.60	9.73	8.25	7.51	6.38	3.56	0.51'	-1.41'	-2.40	-2.98
for seasonal AR(2) u_t:										
with no regressors	6.86	1.28'	0.65'	-0.22'	-0.69'	-2.20	-3.32	-3.85	-4.18	-4.40
with an intercept	8.86	7.68	6.94	6.84	5.85	3.40	0.49'	-1.37'	-2.40	-3.02
with a time trend	9.22	8.65	8.13	7.67	5.95	3.50	0.65'	-1.37'	-2.43	-3.01

$\hat{r}$ in (5) for foreign prices in Canada*

Values of d	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	15.71	13.53	7.68	3.30	-0.03'	-2.04	-3.13	-3.74	-4.12	-4.37
with an intercept	15.71	13.82	11.04	8.04	3.63	0.54'	-1.16'	-2.17	-2.82	-3.28
with a time trend	17.42	15.95	12.87	8.29	3.77	0.60'	-1.21'	-2.23	-2.84	-3.27
for AR(1) u_t:										
with no regressors	--	--	--	--	--	1.36'	-0.49'	-1.74	-2.57	-3.14
with an intercept	--	--	--	--	-0.62'	-1.69	-2.52	-3.05	-3.41	-3.66
with a time trend	--	--	--	-0.18'	-0.31'	-1.56'	-2.54	-3.13	-3.44	-3.65
for AR(2) u_t:										
with no regressors	--	--	--	--	--	4.02	1.72	0.43	-0.24'	-1.63'
with an intercept	--	--	--	--	0.55'	-0.41'	-1.39'	-2.10	-2.61	-2.97
with a time trend	--	--	--	--	0.80'	-0.20'	-1.36'	-2.19	-2.65	-2.94
for seasonal AR(1) u_t:										
with no regressors	6.54	4.99	2.43	0.90'	-0.31'	-2.04	-3.17	-3.78	-4.16	-4.41
with an intercept	6.54	5.88	5.76	5.04	3.47	0.65	-1.16'	-2.21	-2.86	-3.31
with a time trend	10.12	8.60	7.15	5.95	3.57	0.71'	-1.21'	-2.27	-2.88	-3.30
for seasonal AR(2) u_t:										
with no regressors	5.86	1.97	1.22'	0.40'	-0.34'	-2.05	-3.15	-3.76	-4.13	-4.39
with an intercept	6.86	6.71	5.43	4.75	3.19	0.62'	-1.15'	-2.19	-2.85	-3.30
with a time trend	7.74	7.44	7.38	5.84	3.31	0.64'	-1.21'	-2.26	-2.87	-3.30

*: "'" means non-rejection values of the null hypothesis (4) in the one-sided tests at 95% significance level; "--" means that we do not achieve monotonicity in the value of the test statistic across the different values of d.

TABLE 2

$\hat{r}$ in (5) for domestic prices in U.K.*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	15.89	17.69	9.49	4.16	0.47'	-1.73	-2.93	-3.60	-4.02	-4.29
with an intercept	15.89	14.37	12.42	11.82	8.53	4.62	1.97	0.14'	-1.16'	-2.07
with a time trend	18.39	17.68	15.95	12.82	8.90	5.15	2.31	0.20'	-1.40'	-2.40
for AR(1) u_t:										
with no regressors	--	--	--	--	--	1.59'	-0.23'	-1.51'	-2.37	-2.98
with an intercept	--	--	--	--	-0.86'	-1.46'	-2.07	-2.25	-2.57	-2.97
with a time trend	4.50	4.49	1.65	0.14'	-0.03'	-0.95'	-1.27'	-1.69	-2.61	-3.35
for AR(2) u_t:										
with no regressors	--	--	--	--	--	4.52	2.02	0.58'	-0.16'	-1.47'
with an intercept	--	--	--	--	--	--	--	-0.86'	-1.02'	-1.38'
with a time trend	--	--	--	--	--	--	0.03'	0.11'	-0.75'	-1.81
for seasonal AR(1) u_t:										
with no regressors	--	10.13	3.19	1.37'	0.01'	-1.73	-2.96	-3.64	-4.05	-4.33
with an intercept	--	--	6.91	6.73	6.60	4.43	2.01	0.14'	-1.17'	-2.08
with a time trend	12.05	11.22	9.40	8.08	6.84	4.72	2.27	0.19'	-1.41'	-2.41
for seasonal AR(2) u_t:										
with no regressors	6.64	3.14	1.22'	0.32'	-0.26'	-1.92	-3.18	-3.79	-4.14	-4.39
with an intercept	8.64	8.04	7.20	7.15	6.63	4.37	1.86	0.07'	-1.15'	-2.02
with a time trend	8.63	8.24	8.00	7.99	6.84	4.71	2.26	0.19'	-1.42'	-2.42

$\hat{r}$ in (5) for foreing prices in U.K.*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	15.23	13.12	7.80	3.42	0.04'	-2.00	-3.11	-3.74	-4.12	-4.37
with an intercept	15.23	13.23	9.88	6.04	2.41	0.14'	-1.21'	-2.11	-2.74	-3.21
with a time trend	17.14	15.00	10.92	6.16	2.52	0.22'	-1.16'	-2.04	-2.67	-3.16
for AR(1) u_t:										
with no regressors	--	--	--	--	--	1.30'	-0.49'	-1.73	-2.55	-3.11
with an intercept	--	--	--	-1.19'	-1.42'	-2.56	-2.99	-3.19	-3.31	-3.41
with a time trend	1.04'	0.60'	0.51'	0.49'	-1.43'	-2.42	-2.81	-2.94	-3.07	-3.23
for AR(2) u_t:										
with no regressors	--	--	--	--	--	4.34	2.05	0.62'	-0.21'	-1.64
with an intercept	--	--	--	-0.62'	-0.68'	-2.04	-2.73	-3.07	-3.21	-3.25
with a time trend	--	--	--	0.53'	-0.68'	-1.86	-2.46	-2.64	-2.77	-2.88
for seasonal AR(1) u_t:										
with no regressors	5.92	5.15	2.78	1.24'	-0.13'	-2.01	-3.15	-3.77	-4.15	-4.40
with an intercept	--	--	--	5.84	2.99	0.14'	-1.39'	-2.26	-2.84	-3.27
with a time trend	--	--	7.89	6.43	3.10	0.27'	-1.29'	-2.15	-2.75	-3.21
for seasonal AR(2) u_t:										
with no regressors	8.89	3.30	1.83	0.79'	-0.18'	-2.06	-3.18	-3.78	-4.15	-4.41
with an intercept	8.82	8.14	5.80	4.71	2.77	0.43'	-1.04'	-2.02	-2.69	-3.17
with a time trend	9.04	8.99	7.74	5.59	2.89	0.48'	-1.05'	-2.02	-2.67	-3.15

*: "'" means non-rejection values of the null hypothesis (4) in the one-sided tests at 95% significance level; "--" means that we do not achieve monotonicity in the value of the test statistic across the different values of d.

TABLE 3

$\hat{r}$ in (5) for domestic prices in Japan*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	17.71	16.73	13.86	9.19	4.84	1.65	-0.53'	-1.99	-2.95	-3.60
with an intercept	17.71	16.03	13.46	9.92	6.12	3.14	0.79'	-0.95'	-2.21	-3.10
with a time trend	13.91	13.13	11.64	9.15	6.08	3.13	0.77'	-0.95'	-2.19	-3.08
for AR(1) u_t:										
with no regressors	--	--	--	--	--	--	-1.27'	-1.33'	-1.63'	-2.05
with an intercept	--	--	--	--	--	--	-1.38'	-1.46'	-1.55'	-1.77
with a time trend	--	--	--	--	--	--	-1.38'	-1.46'	-1.52'	-1.72
for AR(2) u_t:										
with no regressors	--	--	--	--	--	--	--	--	-2.09	-2.13
with an intercept	--	--	--	--	-1.97	-2.33	-2.76	-3.04	-3.16	-3.16
with a time trend	--	--	--	--	-2.05	-2.30	-2.75	-3.05	-3.15	-3.17
for seasonal AR(1) u_t:										
with no regressors	--	--	--	7.22	5.40	2.20	-0.54'	-2.24	-3.21	-3.80
with an intercept	--	--	--	8.04	6.45	3.84	1.02'	-1.14'	-2.51	-3.35
with a time trend	9.83	9.10	8.49	7.80	6.37	3.84	1.00'	-1.14'	-2.49	-3.34
for seasonal AR(2) u_t:										
with no regressors	8.00	7.63	7.51	7.14	5.50	2.40	-0.51'	-2.29	-3.24	-3.80
with an intercept	9.80	9.62	8.63	8.03	6.47	3.88	1.00'	-1.17'	-2.51	-3.35
with a time trend	8.59	8.50	8.27	7.79	6.39	3.88	0.98'	-1.17'	-2.50	-3.33

$\hat{r}$ in (5) for foreign prices in Japan*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	15.16	12.25	7.73	2.79	-0.22'	-1.68	-2.55	-3.17	-3.64	-3.99
with an intercept	15.16	13.11	9.51	4.58	0.58'	-1.45'	-2.50	-3.14	-3.58	-3.91
with a time trend	16.62	14.07	9.44	4.26	0.58'	-1.42'	-2.49	-3.14	-3.58	-3.91
for AR(1) u_t:										
with no regressors	--	--	--	--	--	1.45'	-1.59'	-2.02	-2.50	-2.95
with an intercept	--	--	--	-0.12'	-1.08'	-2.13	-2.70	-3.04	-3.31	-3.53
with a time trend	--	--	--	-0.18'	-1.05'	-2.07	-2.68	-3.04	-3.31	-3.55
for AR(2) u_t:										
with no regressors	--	--	--	--	--	--	-0.21'	-0.32'	-0.70'	-1.20'
with an intercept	--	--	--	-0.05'	-0.71'	-1.80	-2.40	-2.71	-2.88	-3.00
with a time trend	--	--	--	0.28'	0.68'	-1.70	-2.35	-2.71	-2.92	-3.06
for seasonal AR(1) u_t:										
with no regressors	5.92	4.35	3.64	2.77	-0.07'	-1.86	-2.73	-3.30	-3.72	-4.04
with an intercept	5.92	5.67	4.83	4.31	0.80'	-1.47'	-2.59	-3.21	-3.63	-3.93
with a time trend	8.13	7.36	6.48	4.11	0.80'	-1.42'	-2.58	-3.21	-3.63	-3.94
for seasonal AR(2) u_t:										
with no regressors	6.81	6.43	4.38	2.35	-0.03'	-1.84	-2.72	-3.28	-3.70	-4.02
with an intercept	6.81	6.71	5.39	3.73	0.66'	-1.49'	-2.60	-3.23	-3.65	-3.95
with a time trend	7.34	6.79	6.46	3.76	0.66'	-1.46'	-2.60	-3.23	-3.65	-3.96

*: "'" means non-rejection values of the null hypothesis (4) in the one-sided tests at 95% significance level; "--" means that we do not achieve monotonicity in the value of the test statistic across the different values of d.

TABLE 4

$\hat{r}$ in (5) for domestic prices in France*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	16.57	15.66	12.88	7.75	3.44	0.39'	-1.69	-2.96	-3.71	-4.16
with an intercept	16.57	14.31	11.01	8.82	6.46	3.32	0.47'	-1.53'	-2.75	-3.46
with a time trend	14.91	13.81	12.08	9.67	6.53	3.11	0.24'	-1.67	-2.82	-3.49
for AR(1) u_t:										
with no regressors	--	--	--	--	--	0.03'	-0.17'	-1.05'	-1.89	-2.54
with an intercept	--	--	--	--	--	0.60'	-0.72'	-1.42'	-2.26	-2.96
with a time trend	--	--	--	--	--	0.70'	-0.75'	-1.55'	-2.43	-3.12
for AR(2) u_t:										
with no regressors	--	--	--	--	--	1.98	-0.78'	-0.88'	-1.55'	-2.40
with an intercept	--	--	--	--	--	--	--	-0.90'	-1.23'	-1.73
with a time trend	--	--	--	--	--	--	-0.81'	-0.82'	-1.32'	-1.93
for seasonal AR(1) u_t:										
with no regressors	7.58	6.88	5.93	5.39	3.03	0.34'	-1.68	-2.87	-3.62	-4.11
with an intercept	--	--	--	6.36	5.45	3.10	0.53'	-1.51'	-2.77	-3.50
with a time trend	11.52	10.34	8.97	7.40	5.45	2.95	0.31'	-1.66	-2.85	-3.53
for seasonal AR(2) u_t:										
with no regressors	6.39	5.86	5.81	5.43	3.04	0.37'	-1.63'	-2.88	-3.64	-4.11
with an intercept	7.39	7.18	6.79	6.26	5.22	2.99	0.45'	-1.56'	-2.79	-3.50
with a time trend	8.61	8.36	7.74	6.73	5.18	2.84	0.23'	-1.71	-2.88	-3.55

$\hat{r}$ in (5) for foreign prices in France*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	15.57	12.14	7.30	2.30	-0.75'	-2 26	-3.10	-3.67	-4.08	-4.38
with an intercept	15.57	13.04	8.09	2.32	-0.65'	-2.21	-3.19	-3.84	-4.28	-4.58
with a time trend	13.00	9.48	5.33	1.76	-0.64'	-2.18	-3.18	-3.83	-4.27	-4.57
for AR(1) u_t:										
with no regressors	--	--	--	--	--	0.25'	-0.91'	-1.57'	-2.15	-2.66
with an intercept	--	--	--	-0.44	-0.79'	-1.15'	-1.55'	-2.02	-2.51	-2.97
with a time trend	--	--	--	-0.72'	-0.78'	-1.08'	-1.49'	-1.96	-2.46	-2.94
for AR(2) u_t:										
with no regressors	--	--	--	--	--	0.72'	0.51'	-0.19'	-1.11'	-2.20
with an intercept	--	--	--	--	--	--	-2.53	-2.62	-2.66	-2.68
with a time trend	--	--	--	--	--	-2.41	-2.49	-2.55	-2.55	-2.60
for seasonal AR(1) u_t:										
with no regressors	6.12	4.01	2.91	1.96	-0.69'	-2.45	-3.26	-3.75	-4.12	-4.40
with an intercept	6.12	4.63	5.03	2.80	-0.75'	-2.44	-3.36	-3.95	-4.35	-4.63
with a time trend	9.01	8.26	5.29	2.14	-0.73'	-2.39	-3.33	-3.93	-4.34	-4.62
for seasonal AR(2) u_t:										
with no regressors	9.20	7.15	3.89	1.50'	-0.60'	-2.39	-3.23	-3.72	-4.09	-4.38
with an intercept	9.20	7.68	4.88	2.76	-0.79	-2.48	-3.37	-3.95	-4.35	-4.62
with a time trend	9.01	8.23	5.84	2.21	-0.77'	-2.42	-3.34	-3.93	-4.33	-4.61

*: "'" means non-rejection values of the null hypothesis (4) in the one-sided tests at 95% significance level; "--" means that we do not achieve monotonicity in the value of the test statistic across the different values of d.

TABLE 5

$\hat{r}$ in (5) for domestic prices in Italy*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	16.23	14.80	11.35	6.81	3.35	0.80'	-1.01'	-2.21	-2.98	-3.47
with an intercept	16.23	13.84	10.35	7.65	5.12	2.48	0.31'	-1.19'	-2.14	-2.74
with a time trend	13.16	11.95	10.23	7.94	5.16	2.41	0.22'	-1.26'	-2.18	-2.76
for AR(1) u_t:										
with no regressors	--	--	--	--	--	-1.80	-1.99	-2.45	-2.95	-3.36
with an intercept	--	--	--	--	-1.23'	-1.62'	-2.12	-2.81	-3.41	-3.84
with a time trend	7.85	4.55	2.11	0.40'	-1.27'	-1.59'	-2.13	-2.85	-3.45	-3.87
for AR(2) u_t:										
with no regressors	--	--	--	--	--	--	-0.69'	-0.82'	-1.27'	-1.81
with an intercept	--	--	--	--	--	0.25'	0.18'	-0.35'	-1.13'	-1.92
with a time trend	--	--	--	--	--	0.31'	0.24'	-0.36'	-1.19'	-1.98
for seasonal AR(1) u_t:										
with no regressors	7.38	6.74	6.38	5.48	3.14	0.78'	-1.00'	-2.20	-2.98	-3.50
with an intercept	--	--	--	6.30	4.70	2.45	0.48'	-0.92'	-1.90	-2.60
with a time trend	10.73	9.63	8.39	6.82	4.72	2.37	0.39'	-1.00'	-1.94	-2.62
for seasonal AR(2) u_t:										
with no regressors	6.78	6.64	6.18	5.38	3.10	0.86'	-0.90'	-2.14	-2.97	-3.51
with an intercept	6.78	6.29	6.26	6.02	4.41	2.33	0.46'	-0.92'	-1.90	-2.58
with a time trend	8.11	7.77	7.23	6.17	4.41	2.27	0.38'	-1.00'	-1.94	-2.61

$\hat{r}$ in (5) for foreign prices in Italy*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	14.31	10.79	6.28	1.87	0.80'	-2.17	-2.96	-3.91	-4.08	-4.21
with an intercept	14.31	11.30	6.06	1.22'	-1.00'	-2.20	-2.98	-3.53	-3.94	-4.25
with a time trend	11.94	8.16	4.03	0.93'	-0.98'	-2.19	-2.98	-3.53	-3.94	-4.24
for AR(1) u_t:										
with no regressors	--	--	--	--	--	-1.00'	-1.43'	-1.98	-2.49	-2.93
with an intercept	--	--	--	-1.48'	-1.93	-2.26	-2.49	-2.70	-2.91	-3.13
with a time trend	0.27'	-0.16'	-0.82'	-1.42'	-1.90	-2.22	-2.47	-2.70	-2.91	-3.13
for AR(2) u_t:										
with no regressors	--	--	--	--	--	0.34'	0.34'	-0.12'	-0.71'	-1.37'
with an intercept	--	--	--	-1.93	-2.62	-3.06	-3.27	-3.38	-3.45	-3.50
with a time trend	--	-0.57'	-0.88'	-1.85	-2.58	-3.00	-3.23	-3.37	-3.46	-3.51
for seasonal AR(1) u_t:										
with no regressors	5.54	3.74	2.76	1.81	-0.70'	-2.35	-3.16	-3.65	-4.01	-4.28
with an intercept	5.54	4.23	4.22	1.42'	-1.09'	-2.30	-3.03	-3.56	-3.96	-4.28
with a time trend	8.10	7.24	4.36	1.06'	-1.08'	-2.28	-3.03	-3.56	-3.96	-4.27
for seasonal AR(2) u_t:										
with no regressors	8.62	6.40	3.61	1.53'	-0.59'	-2.34	-3.18	-3.67	-4.02	-4.30
with an intercept	8.62	6.58	3.90	1.59'	-1.02'	-2.25	-2.95	-3.46	-3.86	-4.18
with a time trend	8.07	7.05	4.52	1.26'	-1.01'	-2.22	-2.94	-3.46	-3.86	-4.17

*: "'" means non-rejection values of the null hypothesis (4) in the one-sided tests at 95% significance level; "--" means that we do not achieve monotonicity in the value of the test statistic across the different values of d.

TABLE 6

$\hat{r}$ in (5) for nominal exchange rate in Canada*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	10.92	8.97	5.49	2.26	0.13’	-1.23’	-2.19	-2.89	-3.38	-3.72
with an intercept	10.92	8.80	5.53	2.30	0.13’	-1.23’	-2.20	-2.89	-3.38	-3.72
with a time trend	11.61	8.75	5.16	2.15	0.12’	-1.23’	-2.19	-2.89	-3.38	-3.72
for AR(1) u_t:										
with no regressors	1.85	0.56’	-1.08’	-1.77	-2.18	-2.52	-2.87	-3.25	-3.58	-3.81
with an intercept	1.85	0.34’	-1.00’	-1.68	-2.18	-2.53	-2.88	-3.25	-3.58	-3.81
with a time trend	2.12	0.43’	-1.39’	-1.90	-2.20	-2.52	-2.87	-3.24	-3.58	-3.82
for AR(2) u_t:										
with no regressors	--	--	-0.77’	-0.86’	-1.26’	-1.60’	-1.94	-2.39	-2.87	-3.26
with an intercept	--	--	--	-0.80’	-1.26’	-1.61’	-1.95	-2.40	-2.87	-3.26
with a time trend	--	--	-0.87’	-0.97’	-1.28’	-1.59’	-1.94	-2.38	-2.86	-3.27
for seasonal AR(1) u_t:										
with no regressors	7.61	7.03	5.03	2.26	0.13’	-1.22’	-2.18	-2.90	-3.42	-3.77
with an intercept	7.61	6.84	5.06	2.30	0.13’	-1.22’	-2.19	-2.90	-3.42	-3.77
with a time trend	8.36	7.09	4.81	2.16	0.12’	-1.22’	-2.18	-2.90	-3.42	-3.77
for seasonal AR(2) u_t:										
with no regressors	6.88	6.79	5.00	2.22	0.14’	-1.19’	-2.17	-2.90	-3.42	-3.78
with an intercept	6.68	6.61	5.03	2.27	0.14’	-1.20’	-2.17	-2.91	-3.42	-3.78
with a time trend	7.89	7.09	4.82	2.11	0.12’	-1.19’	-2.17	-2.90	-3.42	-3.78

*: "’" means non-rejection values of the null hypothesis (4) in the one-sided tests at 95% significance level; "--" means that we do not achieve monotonicity in the value of the test statistic across the different values of d.

TABLE 7

$\hat{r}$ in (5) for nominal exchange rate in U.K.*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	15.93	12.27	7.67	2.87	-0.40’	-2.20	-3.19	-3.77	-4.13	-4.36
with an intercept	15.93	13.16	7.52	1.96	-0.08’	-1.07’	-1.78	-2.35	-2.80	-3.17
with a time trend	10.52	6.71	3.51	1.32’	-0.08’	-1.05’	-1.79	-2.37	-2.83	-3.21
for AR(1) u_t:										
with no regressors	--	--	--	--	--	-0.51’	-1.40’	-2.26	-2.87	-3.28
with an intercept	--	--	--	-2.33	-3.14	-3.30	-3.33	-3.36	-3.41	-3.48
with a time trend	2.52	2.09	-0.74’	-2.60	-3.13	-3.28	-3.34	-3.40	-3.47	-3.55
for AR(2) u_t:										
with no regressors	--	--	--	--	--	1.88	1.39’	0.30’	-0.64’	-1.54’
with an intercept	--	--	--	-1.35’	-2.42	-2.74	-2.81	-2.82	-2.89	-2.90
with a time trend	1.13’	0.54’	-0.62’	-1.76	-2.41	-2.70	-2.82	-2.89	-2.91	-2.91
for seasonal AR(1) u_t:										
with no regressors	7.29	5.12	3.71	2.33	-0.36’	-2.25	-3.23	-3.80	-4.16	-4.40
with an intercept	7.28	6.27	6.18	2.32	-0.45’	-1.46’	-2.04	-2.50	-2.89	-3.23
with a time trend	8.34	7.14	4.37	1.39’	-0.45’	-1.43’	-2.04	-2.52	-2.92	-3.26
for seasonal AR(2) u_t:										
with no regressors	11.03	8.05	5.17	2.36	-0.22’	-2.04	-3.11	-3.76	-4.15	-4.41
with an intercept	11.03	8.97	5.72	2.15	-0.01’	-1.03’	-1.74	-2.30	-2.74	-3.11
with a time trend	8.35	6.49	3.88	1.52’	-0.03’	-1.03’	-1.76	-2.33	-2.78	-3.15

*: "’" means non-rejection values of the null hypothesis (4) in the one-sided tests at 95% significance level; "--" means that we do not achieve monotonicity in the value of the test statistic across the different values of d.

TABLE 8

$\hat{r}$ in (5) for nominal exchange rate in Japan*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	18.65	17.69	14.05	9.84	6.20	3.15	0.86'	-0.75'	-1.90	-2.73
with an intercept	18.65	17.23	14.86	11.11	7.26	4.03	1.57'	-0.16'	-1.41'	-2.32
with a time trend	15.54	14.88	13.31	10.63	7.22	4.01	1.56'	-0.16'	-1.41'	-2.32
for AR(1) u_t:										
with no regressors	--	--	--	--	--	--	-1.73	-1.79	-2.02	-2.36
with an intercept	--	--	--	1.96	0.52'	-1.93	-2.28	-2.31	-2.41	-2.60
with a time trend	--	3.17	2.77	1.95	0.58'	-1.94	-2.30	-3.32	-2.42	-2.61
for AR(2) u_t:										
with no regressors	--	--	--	--	--	--	--	--	--	--
with an intercept	--	--	--	--	-1.33'	-1.75	-2.13	-2.31	-2.35	-2.43
with a time trend	--	--	--	--	-1.25'	-1.76	-2.15	-2.32	-2.36	-2.36
for seasonal AR(1) u_t:										
with no regressors	10.51	10.12	8.80	7.84	6.34	3.89	1.24'	-0.70'	-1.95	-2.77
with an intercept	--	--	--	8.68	7.32	4.84	1.99	-0.17'	-1.56'	-2.46
with a time trend	9.04	8.71	8.58	8.40	7.29	4.82	1.98	-0.18'	-1.57'	-2.46
for seasonal AR(2) u_t:										
with no regressors	9.92	9.62	8.84	7.86	6.32	3.89	1.28'	-0.61'	-1.84	-2.69
with an intercept	9.02	8.89	8.73	8.66	7.26	4.83	2.04	-0.04'	-1.40'	-2.34
with a time trend	9.17	9.05	8.57	8.40	7.23	4.82	2.02	-0.04'	-1.41'	-2.34

*: "'" means non-rejection values of the null hypothesis (4) in the one-sided tests at 95% significance level; "--" means that we do not achieve monotonicity in the value of the test statistic across the different values of d.

TABLE 9

$\hat{r}$ in (5) for nominal exchange rate in France*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	16.80	15.10	6.06	2.76	0.21'	-1.68	-2.80	-3.51	-3.98	-4.32
with an intercept	16.80	14.18	9.85	4.62	1.15'	-1.15'	-2.61	-3.49	-4.04	-4.41
with a time trend	15.81	13.36	9.41	4.80	1.14'	-1.25'	-2.67	-3.52	-4.06	-4.41
for AR(1) u_t:										
with no regressors	--	--	--	--	--	-0.67'	-1.08'	-1.67	-2.24	-2.75
with an intercept	--	--	--	--	-0.14'	-0.52'	-1.14'	-1.77	-2.35	-2.86
with a time trend	--	--	--	--	-0.16'	-0.63'	-1.25'	-1.84	-2.39	-2.89
for AR(2) u_t:										
with no regressors	--	--	--	--	--	--	-0.63'	-0.71'	-1.06'	-1.53'
with an intercept	--	--	--	-1.98	-2.04	-2.19	-2.25	-2.28	-2.32	-2.42
with a time trend	--	0.68'	0.47'	-1.02'	-2.05	-2.29	-2.38	-2.40	-2.42	-2.49
for seasonal AR(1) u_t:										
with no regressors	8.01	7.99	5.46	2.94	0.51'	-1.69	-2.99	-3.69	-4.12	-4.42
with an intercept	8.01	6.05	5.96	4.89	1.47'	-1.18'	-2.77	-3.64	-4.15	-4.48
with a time trend	9.40	8.64	7.52	5.03	1.47'	-1.31'	-2.85	-3.68	-4.17	-4.49
for seasonal AR(2) u_t:										
with no regressors	8.92	8.87	5.36	2.85	0.62'	-1.62'	-3.01	-3.72	-4.15	-4.44
with an intercept	8.32	6.94	6.25	4.78	1.46'	-1.18'	-2.76	-3.63	-4.14	-4.76
with a time trend	9.03	8.87	7.40	4.85	1.46'	-1.31'	-2.85	-3.66	-4.16	-4.48

*: "'" means non-rejection values of the null hypothesis (4) in the one-sided tests at 95% significance level; "--" means that we do not achieve monotonicity in the value of the test statistic across the different values of d.

TABLE 10

$\hat{r}$ in (5) for the nominal exchange rate in Italy*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
wIth no regressors	16.75	15.49	9.47	5.22	1.87	-0.69’	-2.27	-3.19	-3.74	-4.10
with an intercept	16.75	14.35	10.79	7.12	3.50	0.44’	-1.63’	-2.85	-3.56	-3.98
with a time trend	14.55	13.04	10.59	7.23	3.50	0.37’	-1.69	-2.89	-3.58	-4.00
for AR(1) u_t:										
with no regressors	--	--	--	--	--	-0.71’	-1.12’	-1.90	-2.57	-3.09
with an intercept	--	--	--	--	--	-0.37’	-1.22’	-2.14	-2.86	-3.37
with a time trend	--	--	--	--	--	-0.41’	-1.29’	-2.22	-2.93	-3.42
for AR(2) u_t:										
with no regressors	--	--	--	--	--	--	0.16’	-0.11’	-0.71’	-1.35’
with an intercept	--	--	--	--	--	-0.85’	-0.89’	-1.38’	-1.96	-2.49
with a time trend	--	--	--	--	--	-0.85’	-0.94’	-1.49’	-2.09	-2.60
for seasonal AR(1) u_t:										
with no regressors	--	9.45	6.48	3.86	1.63’	-0.65’	-2.30	-3.24	-3.79	-4.14
with an intercept	8.18	6.49	6.26	3.81	3.14	0.42’	-1.67	-2.88	-3.59	-4.02
with a time trend	10.81	9.42	7.83	5.79	3.14	0.35’	-1.70	-2.92	-3.61	-4.03
for seasonal AR(2) u_t:										
with no regressors	8.57	8.29	5.81	3.67	1.63’	-0.61’	-2.28	-3.24	-3.79	-4.15
with an intercept	6.57	6.51	6.18	5.70	3.08	0.39’	-1.65	-2.88	-3.58	-4.00
with a time trend	8.03	8.03	7.23	5.59	3.07	0.33’	-1.71	-2.92	-3.60	-4.01

*: "’" means non-rejection values of the null hypothesis (4) in the one-sided tests at 95% significance level; "--" means that we do not achieve monotonicity in the value of the test statistic across the different values of d.

TABLE 11

$\hat{r}$ in (5) for real exchange rate in Canada*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	8.66	6.46	4.26	2.17	0.31’	-1.22’	-2.38	-3.17	-3.68	-4.00
with an intercept	8.66	6.53	4.07	1.72	0.18’	-1.54’	-2.49	-3.14	-3.58	-3.88
with a time trend	8.82	6.71	4.24	1.74	-0.19’	-1.54’	-2.49	-3.14	-3.58	-3.87
for AR(1) u_t:										
with no regressors	1.81	-0.33’	-0.99’	-1.71	-1.76	-2.28	-2.95	-3.48	-3.48	-3.84
with an intercept	1.81	-0.41’	-1.68	-1.73	-2.04	-2.43	-2.89	-3.34	-3.69	-3.94
with a time trend	2.12	0.18’	-1.61’	-1.83	-2.06	-2.43	-2.89	-3.34	-3.69	-3.93
for AR(2) u_t:										
with no regressors	--	--	--	--	-0.32’	-0.43’	-1.85	-1.98	-2.15	-2.71
with an intercept	--	--	--	-0.97’	-1.16’	-1.40’	-1.79	-2.31	-2.83	-3.23
with a time trend	--	--	-1.03’	-1.06’	-1.18’	-1.40’	-1.78	-2.31	-2.82	-3.21
for seasonal AR(1) u_t:										
with no regressors	7.22	6.12	4.31	2.22	0.29’	-1.25’	-2.40	-3.19	-3.71	-4.03
with an intercept	7.22	6.15	4.12	1.74	-0.18’	-1.54’	-2.50	-3.17	-3.62	-3.92
with a time trend	7.71	6.35	4.20	1.75	-0.19’	-1.55’	-2.50	-3.17	-3.62	-3.92
for seasonal AR(2) u_t:										
with no regressors	5.89	5.21	3.64	1.93	0.38’	-1.08’	-2.30	-3.17	-3.73	-4.07
with an intercept	5.89	5.28	3.37	1.34’	-0.32’	-1.55’	-2.48	-3.16	-3.62	-3.92
with a time trend	7.33	6.04	3.81	1.39’	-0.33’	-1.55’	-2.48	-3.16	-3.61	-3.92

*: "’" means non-rejection values of the null hypothesis (4) in the one-sided tests at 95% significance level; "--" means that we do not achieve monotonicity in the value of the test statistic across the different values of d.

TABLE 12

$\hat{r}$ in (5) for real exchange rate in U.K.[*]

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	10.72	10.59	7.19	3.51	0.53’	-1.47’	-2.72	-3.49	-3.95	-4.25
with an intercept	10.72	7.30	4.19	1.88	0.27’	-0.97’	-1.95	-2.67	-3.21	-3.60
with a time trend	10.24	7.09	4.14	1.88	0.27’	-0.97’	-1.91	-2.55	-3.06	-3.49
for AR(1) u_t:										
with no regressors	--	--	--	--	--	-1.81	-1.82	-1.93	-2.59	-3.08
with an intercept	2.44	-1.35’	-1.40’	-2.39	-2.56	-2.71	-2.89	-3.07	-3.24	-3.40
with a time trend	1.82	0.91’	-1.54’	-2.38	-2.56	-2.70	-2.80	-2.86	-2.89	-3.01
for AR(2) u_t:										
with no regressors	--	--	--	--	--	--	--	-1.79	-1.92	-2.13
with an intercept	-0.77’	-0.96’	-1.42’	-1.88	-2.25	-2.54	-2.74	-2.86	-2.89	-2.89
with a time trend	--	-1.18’	-1.44’	-1.88	-2.25	-2.53	-2.62	-2.68	-2.73	-2.77
for seasonal AR(1) u_t:										
with no regressors	8.82	6.60	5.44	3.60	0.61’	-1.56’	-2.81	-3.53	-3.99	-4.28
with an intercept	8.82	7.80	5.13	2.25	0.15’	-1.23’	-2.17	-2.82	-3.29	-3.65
with a time trend	8.72	7.61	5.08	2.25	0.15’	-1.22’	-2.11	-2.67	-3.12	-3.53
for seasonal AR(2) u_t:										
with no regressors	8.71	7.09	5.57	3.56	0.72’	-1.40’	-2.68	-3.48	-3.97	-4.28
with an intercept	8.71	7.51	5.05	2.46	0.63’	-0.71’	-1.76	-2.56	-3.14	-3.56
with a time trend	8.64	7.32	4.97	2.46	0.63’	-0.69’	-1.71	-2.41	-2.96	-3.43

*: "’" means non-rejection values of the null hypothesis (4) in the one-sided tests at 95% significance level; "--" means that we do not achieve monotonicity in the value of the test statistic across the different values of d.

TABLE 13

$\hat{r}$ in (5) for real exchange rate in Japan[*]

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	13.75	9.61	6.20	2.35	-0.45’	-2.05	-2.97	-3.55	-3.95	-4.23
with an intercept	13.75	10.04	5.12	1.22’	-0.97’	-2.15	-2.86	-3.36	-3.72	-4.01
with a time trend	13.90	9.66	4.75	1.11’	-0.97’	-2.14	-2.86	-3.36	-3.74	-4.02
for AR(1) u_t:										
with no regressors	--	--	--	--	--	1.67	-1.69	-1.73	-2.43	-2.98
with an intercept	-0.24’	-0.33’	-0.42’	-1.24’	-2.14	-2.66	-2.97	-3.21	-3.43	-3.64
with a time trend	0.42’	0.23’	-0.05’	-1.28’	-2.14	-2.65	-2.98	-3.23	-3.47	-3.69
for AR(2) u_t:										
with no regressors	--	--	--	--	---	--	1.79	1.68	-0.10’	-1.00’
with an intercept	--	--	-0.22’	-0.85’	-1.81	-2.36	-2.62	-2.75	-2.83	-2.92
with a time trend	--	0.21’	0.19’	-0.89’	-1.80	-2.34	-2.62	-2.80	-2.93	-3.04
for seasonal AR(1) u_t:										
with no regressors	6.21	3.52	2.39	1.56’	-0.28’	-2.13	-3.09	-3.64	-4.01	-4.28
with an intercept	6.21	5.32	5.04	1.60	-0.97’	-2.27	-2.97	-3.43	-3.76	-4.02
with a time trend	7.80	7.28	4.93	1.46’	-0.97’	-2.26	-2.97	-3.44	-3.77	-4.03
for seasonal AR(2) u_t:										
with no regressors	7.41	4.90	3.11	1.56’	-0.18’	-2.16	-3.14	-3.67	-4.03	-4.29
with an intercept	7.41	6.39	4.39	1.40’	-0.99’	-2.27	-2.98	-3.44	-3.78	-4.03
with a time trend	8.29	7.04	4.47	1.31’	-0.99’	-2.26	-2.98	-3.45	-3.79	-4.05

*: "’" means non-rejection values of the null hypothesis (4) in the one-sided tests at 95% significance level; "--" means that we do not achieve monotonicity in the value of the test statistic across the different values of d.

TABLE 14

$\hat{r}$ in (5) for real exchange rate in France*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	11.38	10.82	6.85	2.59	-0.51'	-2.23	-3.16	-3.72	-4.10	-4.36
with an intercept	8.78	5.62	2.95	0.71'	-1.06'	-2.37	-3.29	-3.90	-4.31	-4.59
with a time trend	6.53	4.80	2.80	0.70'	-1.06'	-2.37	-3.28	-3.88	-4.29	-4.57
for AR(1) u_t:										
with no regressors	--	--	--	--	0.11'	0.70'	-0.70'	-1.78	-2.39	-2.92
with an intercept	--	--	--	-1.33'	-1.06'	-1.23'	-1.74	-2.15	-2.65	-3.12
with a time trend	--	--	--	1.34'	-1.06'	-1.23'	-1.73	-2.09	-2.57	-3.04
for AR(2) u_t:										
with no regressors	-1.88	-5.88	-7.88	-15.81	--	--	--	--	--	--
with an intercept	-1.88	-1.92	-2.83	-3.11	--	--	--	--	--	--
with a time trend	-2.39	-3.03	-3.08	-3.14	--	--	--	--	--	--
for seasonal AR(1) u_t:										
with no regressors	8.05	3.38	2.07	1.04'	-0.48'	-2.28	-3.24	-3.77	-4.13	-4.39
with an intercept	8.05	6.03	3.31	0.72'	-1.26'	-2.57	-3.43	-4.00	-4.38	-4.64
with a time trend	6.73	5.21	3.10	0.69'	-1.26'	-2.57	-3.42	-3.98	-4.35	-4.62
for seasonal AR(2) u_t:										
with no regressors	8.20	5.90	3.25	1.11'	-0.38'	-2.25	-3.25	-3.78	-4.13	-4.39
with an intercept	8.20	6.25	3.17	0.40'	-1.48'	-2.67	-3.47	-4.01	-4.39	-4.65
with a time trend	6.62	4.99	2.80	0.36'	-1.48'	-2.67	-3.46	-3.99	-4.36	-4.63

*: "'" means non-rejection values of the null hypothesis (4) in the one-sided tests at 95% significance level; "--" means that we do not achieve monotonicity in the value of the test statistic across the different values of d.

TABLE 15

$\hat{r}$ in (5) for the real exchange rate in Italy*

Values of d:	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
for white noise u_t:										
with no regressors	12.12	10.02	6.42	2.41	-0.52'	-2.18	-3.10	-3.65	-4.02	-4.29
with an intercept	7.12	4.45	2.06	0.15'	-1.25'	-2.27	-2.99	-3.52	-3.90	-4.20
with a time trend	7.04	4.41	2.05	0.15'	-1.25'	-2.27	-2.99	-3.52	-3.90	-4.20
for AR(1) u_t:										
with no regressors	--	--	--	--	--	-1.74	-1.84	-1.91	-2.52	-3.03
with an intercept	0.35'	-2.08	-2.20	-2.23	-2.26	-2.47	-2.70	-2.92	-3.12	-3.31
with a time trend	0.04'	-2.04	-2.19	-2.22	-2.26	-2.47	-2.70	-2.97	-3.13	-3.32
for AR(2) u_t:										
with no regressors	--	--	--	--	--	-1.66	-1.74	-1.77	-1.88	-2.20
with an intercept	--	-2.14	-2.21	-2.44	-2.71	-2.96	-3.19	-3.36	-3.48	-3.58
with a time trend	--	-2.09	-2.20	-2.44	-2.71	-2.96	-3.19	-3.37	-3.50	-3.60
for seasonal AR(1) u_t:										
with no regressors	6.64	3.31	2.09	1.22'	-0.37'	-2.22	-3.21	-3.74	-4.09	-4.34
with an intercept	6.64	4.60	2.17	0.11'	-1.33'	-2.32	-3.02	-3.54	-3.93	-4.23
with a time trend	6.66	4.58	2.16	0.11'	-1.33'	-2.32	-3.02	-3.54	-3.93	-4.23
for seasonal AR(2) u_t:										
with no regressors	6.65	5.44	3.16	1.28'	-0.29'	-2.24	-3.26	-3.78	-4.11	-4.35
with an intercept	6.65	4.67	2.14	0.01'	-1.42'	-2.35	-3.00	-3.50	-3.88	-4.18
with a time trend	6.70	4.66	2.11	-0.01'	-1.42	-2.35	-3.00	-3.50	-3.88	-4.17

*: "'" means non-rejection values of the null hypothesis (4) in the one-sided tests at 95% significance level; "--" means that we do not achieve monotonicity in the value of the test statistic across the different values of d.

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