Exchange Rates and Fundamentals: Is there a Role for Nonlinearities in Real Time?

Yunus Aksoy[*]

Birkbeck College, University of London

Kurmaş Akdoğan

Birkbeck College, University of London and Central Bank of the Republic of Turkey

First draft: September 2005

This draft: October 2005

Abstract: We examine out of sample predictive power of real time monetary models with nonlinear adjustment in forecast errors for the Pound Sterling/US Dollar exchange rates. Real time revisions of U.K. and U.S. monetary aggregates and output are significant. By studying recursive out of sample forecast errors we claim that in several instances, real time fundamental equilibrium values of exchange rates may be determined in a linear fashion, whereas adjustment towards the fundamentals driven equilibrium values may take a discrete or smooth nonlinear form. Revisions in fundamentals, particularly in the US and UK monetary aggregates and real output, seem to matter mainly for short term forecastability of exchange rates. We find in some real time vintages short term forecastability in the form of discrete nonlinear adjustment. We also document long term forecastability in the form of smooth nonlinear adjustment towards fundamentals determined equilibrium value of exchange rates.

JEL Classification: F31, F37

Keywords: monetary model, exchange rates, nonlinear adjustment, real time, unit roots, forecasting

Corresponding author: Yunus Aksoy: Birkbeck College, University of London, Malet Street, London, WC1E 7HX United Kingdom, Phone: (020) 7631 6428, Fax: (020) 7631 6416. e-mail: yaksoy@econ.bbk.ac.uk

We are grateful to Anthony Garratt and John Rogers for providing part of the data used in this study and to Miguel Leon-Ledesma and Ron Smith for useful comments. The usual disclaimer applies.

1. Introduction

One of the most frequently studied puzzles in international monetary economics is the failure of standard linear monetary models of exchange rates to forecast variations in the exchange rates in the short run. Ever since Meese and Rogoff's (1983) work on out of sample forecast comparison of varieties of monetary models of exchange rates and naïve random walk model, a consensus view has emerged that monetary models are largely unsuccessful in forecasting exchange rates at least in the short term. This literature casts doubts about the suitability of economic models based on fundamentals in forecasting exchange rates (see for evidence based on surveys, Cheung and Chinn, (2001) or Marsh et al. (2004)).

The work of Mark (1995) revived interest in monetary models by focusing on long term predictability of exchange rates. From this perspective, models based on fundamentals are essentially valid in the long run. That means there is a tendency in the exchange rates to adjust to their long term values as suggested by the fundamentals. With the use of nonparametric bootstrapping methods, he was able to show that monetary models with linear mean reversion are of better use in predicting exchange rates in long horizons rather than short horizons. He found that there is some out of sample predictability for Japanese Yen, German Mark and Swiss Frank exchange rates vis-à-vis US Dollar at 12 and 16 quarters forecast horizons.

Mark's (1995) work has been subject to criticism on several grounds. Firstly, Berkowitz and Giorgianni (2001) argue that distribution of the bootstrap test statistic as implemented by Mark depends on the assumption of cointegration between the fundamentals and exchange rates. Given that Mark assumes cointegration between fundamentals and exchange rates to generate bootstrap critical values, if fundamentals and exchange rates are not cointegrated in actual data, critical values and therefore inference from the test would be incorrect. Berkowitz and Giorgianni report very weak evidence of cointegration in the data. Kilian (1999) findings corroborate this view. He finds that even if there is cointegration between fundamentals and exchange rates, mean reversion in forecast errors are very slow. Secondly, data generating process and assumed mean reversion has been criticized. Since the work of Neftci (1984), it has been increasingly popular to test for non-linearities and structural instabilities in economic time series. Enders and Granger (1998) show that if these non-linearities are prevalent under the alternative of stationarity, linear tests for unit roots suffer from a lack of power. Not surprisingly, Kilian and Taylor (2003) show if there is evidence of nonlinear mean reversion standard tests of long-horizon predictability of exchange rates are invalidated. Finally, Faust, Rogers and Wright (2003) argue that data on fundamentals are subject to continuous revisions. They show that Mark linear adjustment results are mainly outcome of a certain window of vintages of real time dataset and therefore are not generally valid.

Failure of linear versions of monetary models to predict exchange rates even in the long run led a number of researchers to explore nonlinear data generation process in the long term adjustment of exchange rates towards their equilibrium value given by the fundamentals. In this view, fundamental based models with an appropriately modelled nonlinear mean revision will be useful in forecasting exchange rates at least in the long run. Recent work by Balke and Fomby (1997), Taylor and Peel (2000), Taylor, Peel and Sarno (2001) and Kilian and Taylor (2003) all investigate the case where nominal exchange rates are not too responsive to variations in the fundamentals (in the case of Kilian and Taylor (2003) and Taylor, Peel and Sarno (2001) price level differentials) when the deviations from equilibrium values are small, but exhibit strong or smooth mean reversion when the deviations are too large. Indeed, they find evidence of adjustment of this type.

Several authors motivate the presence of nonlinear adjustment dynamics towards the long term equilibrium value of exchange rates. Two prominent explanations are transaction costs and heterogeneity in the beliefs/players. In the transaction costs argument, although financial agents are rational, there are transaction costs in the financial markets that create a band within which exchange rates do not respond to small deviations from the long term equilibrium. For large deviations however there is a tendency to revert to the fundamental equilibrium to exploit profitable arbitrage activity. In this view the speed of mean reversion towards equilibrium increases in the deviations from the fundamental equilibrium calling for nonlinearity in the adjustment. The heterogeneity argument on the other hand is motivated by the existence of heterogeneous agents using different information sets (chartists versus fundamentalists in De Grauwe and Dewachter (1993) or noise traders versus rational speculators in Kilian and Taylor (2003)). In the case of Kilian and Taylor, agents cannot form a consensus view over the underlying fundamental equilibrium if the deviations are small. In that case, we can expect to observe random walk behaviour of exchange rates at values close to long term equilibrium value. As the deviations from the long term equilibrium value are getting large, rational speculators will take a stronger position and prevail.[1] Eventually mean reversion occurs towards the unobserved long term equilibrium value of exchange rates. Nonlinear adjustment is apparent.[2]

The key question is how rational agents form their expectations about the equilibrium value of exchange rates based on the fundamentals. Even though observed real time data

---

[1] Clearly, this may include cases where some or all noise traders become rational speculators as deviations become larger.

[2] Of course there are many other explanations, particularly herd behaviour, that call for nonlinear adjustments within behavioural finance framework based on the early works of Shiller (1984) and Kindleberger (1989). See for instance, De Grauwe and Grimaldi (2005) for a recent survey.

[3] Recently, importance of real time data in macroeconomic evaluations has been addressed by several authors. Debate essentially concentrates about the nature of the revisions, i.e. whether these are news (Data are optimal forecasts, so revisions are orthogonal to early data, therefore revisions are not forecastable) or noise (Data are measured with error, so revisions are orthogonal to final data therefore revisions are forecastable). For example Mankiw et al. (1984) find that U.S. money data revisions reduce noise. Faust et al. (2005) examine G-7 countries' output forecasts and find that Italy, Japan & U.K. output revisions forecastable in real time whereas US output revisions are not. Policy analysis in real time received attention with the works of Orphanides (2001), and Faust et al. (2003) among others. Orphanides finds that simple monetary policy rules fit interest rate policy implemented in the 1970's better when real time data instead of ex-post revised data is used. Orphanides and van Norden (2002) assess usefulness of output gap measures for predicting inflation. They show that forecast performance of real time output gap estimates are weak and unstable with respect to simple bivariate forecasting models that use past inflation and output growth, casting doubts over the usefulness of output gap concept in forecasting inflation. For further discussion on the matter see also Croushore and Stark (2003).

on exchange rates and interest rates are valid at all time periods, monetary aggregates, output and prices are subject to regular revisions. Given that finance professionals and policymakers possess only real time data at the time of the forecast, and if they are not able to perfectly predict future data revisions of the macroeconomic fundamentals, they will likely form their exchange rates expectations based on the data publicly available at the time when the forecast are made. An econometric study that implements monetary model based on revised data therefore may yield incorrect inference if the time series properties are significantly altered after the revisions. Several authors find that revisions to preliminary GDP data are large and in general far from being predictable.[3]

In this paper, we extend the real time critique of Faust et al. (2003) to capture dynamic nonlinear adjustment towards fundamental equilibrium values of pound sterling/US Dollar exchange rates. As there is no consensus in the literature about the likely form of nonlinear adjustment, we study two different nonlinear adjustment models. For instance, in case transaction costs are uniformly distributed among financial agents, one can expect a sharp correction in the exchange rates towards the value dictated by the fundamentals once the uniform transaction costs band is reached. Threshold autoregressive (TAR) model (Tong, 1990) appears to be more suitable form of nonlinear model to account for the discrete adjustment in exchange rates.[4] Alternatively, if transaction costs are not uniformly distributed, therefore there exists a continuum of thresholds; smooth nonlinear adjustment might be expected. In this case exchange rate behaviour is possibly more appropriately modelled in the form of smooth nonlinear adjustment as suggested by Granger and Teräsvirta (1993) and Teräsvirta (1994).

We first find that, data revisions, particularly in the case of output and broad monetary aggregates, are very significant on both sides of the Atlantic. Price level data are rarely

[4] TAR model seems to fit well with the observed exchange rate behaviour such as volatility and jumps in the short run (see Coakley and Fuertes (2001)).
[5] For applications of the Kapetanios et al. (2003) test in the context of real exchange rates see, for instance, Choratreas and Kapetanios (2004).

revised. Second, in order to account for both the transaction and noise traders versus rational speculators (or chartists versus fundamentalists) arguments, we implement two different nonlinear unit root tests (TAR and ESTAR) where we take into account both types of potential nonlinearity and unit roots. We find some evidence of nonlinear mean reversion in the out of sample forecast errors over 1 to 16 quarters forecast horizons. More specifically discrete nonlinear mean reversion is observed in shorter term out of sample forecast errors, whereas smooth (exponential) form mean reversion is observed in longer term out of sample forecast errors. An implementation of the TAR unit root test suggest that up to 25% of the real time vintages exhibit a discrete form nonlinear mean reversion within 1 quarter forecast horizon and up to 44% of the vintages exhibit a discrete form nonlinear mean reversion within 2 quarters forecast horizon when we consider real time monetary aggregates and real output in our specification. We are unable to detect discrete form nonlinear mean reversion in longer term out of sample forecast errors. However, an implementation of the ESTAR nonlinear unit root test developed by Kapetanios, Shin and Snell (2003) show that there is indeed evidence of nonlinear smooth mean reversion in the long term out of sample forecast errors in some of the real time estimations when only price levels (that are hardly subject to revisions) are taken into account.[5] In real time 'real exchange rate' estimations, where only price levels are used as fundamentals, in about half of the real time estimations nonlinear mean reversion occurs within 16 quarters forecast horizon at 5% significance level. Similarly, in about 20% of estimations nonlinear mean reversion occurs within 4 quarters forecast horizon at 5% significance level. In alternative monetary models where monetary aggregates and real output are taken into account we find very little evidence of smooth nonlinear mean reversion.

We thus claim that in several instances, real time fundamental equilibrium values of exchange rates may be determined in a linear fashion, whereas adjustment towards the fundamentals driven equilibrium values may take a discrete or smooth nonlinear form. Revisions in fundamentals, particularly, in the US and UK monetary aggregates and real output, seem to matter mainly for short term forecastability of exchange rates lending support to the work of Faust et al. (2003). We find in some real time vintages short term forecastability in the form of discrete nonlinear adjustment. We also document long term forecastability in the form of smooth nonlinear adjustment towards fundamentals determined equilibrium value of exchange rates. This provides some supporting evidence for the work of Taylor and Peel (2000), Taylor, Peel and Sarno (2001) and Kilian and Taylor (2003) who claim smooth nonlinear adjustment in real exchange rates.

The paper is organised as follows. Section 2 provides a discussion on the importance of data revisions and the real time dataset we use in the paper. Section 3 presents results for two possible nonlinear models (TAR and ESTAR) and discuss related non-linear unit root tests. Finally, Section 4 concludes.

2. Real Time Datasets and Data Revisions

First, we would like to clarify the notation that will be used throughout the paper. Let us define the final value of a variable as follows;

$$x_t^f = x_t^{t+1} + r_t^f$$

where x_t^{t+1} denote a statistical agency's initial announcement (at *t+1*) of a variable that was realized at time t, x_t^f denote the final or true value of the same variable, and r_t^f is the final revision which can potentially be never observed.

We possess real time U.K. and U.S. monetary aggregates, real output and price level data as of period 1977Q1 onwards for each quarter (vintages). As exchange rates are never revised we use quarterly end of period Pound Sterling/US Dollar exchange rates made available by the IMF/IFS. As we are interested in working with sufficiently long data, we will use 1977Q1 to 1984Q4 vintages for constructing the *first* operational real time dataset for the vintage 1985Q1. In practice this means we will have 16 quarterly real time datasets for the 1985Q1 - 1989Q1 sample (excluding 1988Q3). Our shortest vintage, corresponding to the first vintage (1985Q1) contains 57 quarterly data points, while the longest vintage, corresponding to the latest vintage (1989Q1), contains 74 quarterly data points.[6] It is important first to note that revised statistics provided in economic bulletins cover only a limited time period up to 16 quarters, i.e. data revisions published do not stretch up to the beginning of the sample period. Therefore, in line with Orphanides (2001), and Faust et al. (2003) we assume that there was no further official revision in data concerning the time period that was not published in the latest bulletin.[7] This allows us to extend the data backwards with the data published in the previous economic bulletins. Secondly, monetary aggregates data we possess are end of period of £M3 for the UK and quarterly average of M2 for the US. As this data was published consistently in economic bulletins for the specified time period as such, we assume that finance professionals made use of this available real time data. Further source details are provided in Appendix A.

---

[6] We restrict sample period due to data limitations in the UK monetary aggregates. Office for National Statistics (formerly known as Central Statistical Office) in the UK published £M3 data continuously up to August 1989 (under the name of M3 after August 1987, whereas the old M3 is renamed as M3c after this date). After August 1989, UK statistical agency ceased to publish M3 and M3c, and publish M4c data which is a redefinition of M4 introduced in May 1987. Given that UK joined Exchange Rate Mechanism between 1990 and 1992, where the monetary policy was effectively delegated to the German Bundesbank, we prefer to use M3 data.

[7] For example January 1986 issue of Economic Trends provides statistics from January 1981 to December 1985, which amounts to 16 data points. We assumed that there is no revision in data covering *before January 1981*. Note that this assumption can be justified as follows. Even if there was some revision for the earlier sample periods, we assume that finance professionals were using fundamentals data as 'published' (i.e. made publicly available) by the official economic agents rather than having some privileged access to the full sample revised data.

[8] We only report changes vis-à-vis the first announcement. See Table notes.

Insert Table 1 about here

In Table 1 we report detailed information on the size of revisions for each individual data point over 16 vintages and the average size of revisions in monetary aggregates, real output and price levels. We report revisions for each individual data point as found in the bulletins published one, two, four, eight or sixteen quarters after the initial announcement.[8]

Typically, well behaved revisions have three characteristics.[9] First, revisions are expected to be mean zero. i.e. initial announcement of the statistical agency is an unbiased estimate of the final value. Secondly, variance of the final revision should be small compared to the variance of the final value. Thirdly, final revision should be unpredictable given the information set at the time of the initial announcement.

In our case, data revisions are not well behaved. Several points are worth to comment. First, quarter to quarter data revisions are frequent and can be large and volatile in the case of both US and UK monetary aggregates and the real output. Revisions do not have zero mean. We do not report the revisions in the US and the UK price levels since they are less frequent and if there are revisions, these are rather small. Secondly, as shown in Table 1, revisions stretch backwards for several years suggesting that revisions are continuous. As quarters pass by, average size of revisions becomes larger throughout. Finally, while Mankiw et al. (1984) find that U.S. money data revisions reduce noise Faust et al. (2005) examine G-7 countries' output forecasts and find that Italy, Japan & U.K. output revisions are forecastable in real time whereas US output revisions are not.

3. Monetary Exchange Rate Models

We assume that the financial agents use the real time (initial announcement) data in forming their exchange rate forecasts. We use uppercase letters to indicate the initial

[9] See for instance Aruoba (2005).

[10] See for instance Stockman (1987) for a microfounded justification of monetary models of exchange rates.

announcement and lower case letters to indicate the time announced data refers. The real time fundamental value of the log exchange rate at time t based on the initial announcement for fundamentals at time $t+1$ (f_t^{t+1}) is predicted by the simple nested monetary model that takes the following form.[10]

$$f_t^{t+1} = \alpha_1(m_t^{t+1,US} - m_t^{t+1,UK}) + \alpha_2(y_t^{t+1,US} - y_t^{t+1,UK}) + \alpha_3(p_t^{t+1,US} - p_t^{t+1,UK}) \qquad (1)$$

where m_t^{t+1}, y_t^{t+1} and p_t^{t+1} are the logs of US and UK real time money aggregates, US and UK real time output and US and UK price levels at time t based on the initial announcement at time $t+1$. We will consider four models where *MPY Model* is the full specification, *MY Model* imposes $\alpha_3=0$, *PY Model* imposes $\alpha_1=0$, and finally *P Model* (real exchange rate model) imposes $\alpha_1= \alpha_2=0$. We define the deviations of exchange rate from the value determined by the fundamentals (via equation (1)) as being;

$$z_t^{t+1} = f_t^{t+1} - s_t \qquad (2)$$

The out-of-sample test are implemented based on a sequence of real time recursive forecasts ($\tilde{z}_{t+k}$), starting with a sample size of 20 quarters. Series of out of sample forecasts for a given forecast horizon $k=1, 2, 4, 8, 16$ are computed with data up to date $t_0<T$ and recursively adding up one observation up to period $T-k$. Given that we want to

---

[11] Note that instead of looking at the recursive out of sample forecast errors, Mark (1995) estimates an error correction specification (ECM) to generate out of sample forecast errors. We opt for the recursive out of sample forecast errors instead of relying on the out of sample forecast errors based on the error correction specification due to critiques of Berkowitz and Giorgianni (2001), Kilian (1999) and Kilian and Taylor (2003). In Berkowitz and Giorgianni (2001) it is argued that if the f_t^{t+1} and s_t are not cointegrated in the real data, then the critical values will be incorrect. This is because the ECM forecasting regression will be almost a spurious regression. As the forecast horizon, k, increases, changes in the exchange rate becomes more persistent, yet estimated coefficients will be significant, signalling potential spurious nature of the estimation (see also Neely and Sarno (2002)). On the other hand Kilian (1999) and Kilian and Taylor (2003) show that if the true process is nonlinear, these critical values are invalid under the null hypothesis and the resulting bootstrap *p*-values cannot be given meaningful interpretations. Therefore, we prefer to give financial professional some informational advantage by providing contemporaneous values of the fundamentals (right hand side variables) in generating our out of sample forecast errors.

work with a minimum of 20 out of sample forecast errors in a given exercise we restrict the number of vintages to work with to 16. First operational vintage dates to 1985Q1 and final operational vintage is 1989Q1. This leaves us with a minimum of 57 data points in each estimation.[11]

Given the recent evidence on nonlinear adjustment in out of sample forecast errors (Taylor and Peel (2000), Taylor, Peel and Sarno (2001) and Kilian and Taylor (2003)) we implement nonlinear unit root tests for out of sample forecast errors. In the following section we will allow for two types of out of sample forecast error adjustment dynamics of exchange rates towards the fundamentals based equilibrium evaluated in real time.[12] We first analyze an immediate transition threshold analysis a la Tong (1990) with unit root extension by Caner and Hansen (2001). Second model we consider is the more realistic exponential smooth transition threshold dynamics model (ESTAR Model) of Granger and Teräsvirta (1993) with unit root testing extensions by Kapetanios et al.(2003).

TAR Unit Root Tests *(Caner and Hansen (2001)):* We postulate following equation (3) as an appropriate TAR Model.

$$\Delta\tilde{z}_{t+k} = I_t\left[\theta_1^{'}\tilde{z}_{t+k-1} + \sum_{j=1}^{p}\gamma_{1j}\Delta\tilde{z}_{t+k-j}\right] + (1-I_t)\left[\theta_2^{'}\tilde{z}_{t+k-1} + \sum_{j=1}^{p}\gamma_{2j}\Delta\tilde{z}_{t+k-j}\right] + \zeta_t\,, \qquad (3)$$

where $z_{t-1} = (1\ t\ \ z_{t-1})$, ζ_t is an iid error, and I_t is the indicator function that takes the form

[12] We have also conducted tests of linear monetary model with linear adjustment in the forecast errors akin to Meese and Rogoff (1983), Mark (1995) and more particularly Kilian (1999). We document wide evidence of failure of the linear specifications in the adjustment process towards fundamental equilibrium value of exchange rates in real time. Naïve random walk models without a drift parameter always beat monetary models assessed based on the 30 real time vintages of data. For the sake of brevity we do not report these results however these are available upon request from authors.

[13] In practice, outliers are eliminated by trimming the series for the highest and lowest values of Δy_{t-m}

$$I_t = \begin{cases} 1 & if \quad y_{t-1} < \lambda \\ 0 & if \quad y_{t-1} \geq \lambda \end{cases}.$$

where λ is a threshold and the variable y_t is any stationary variable that would determine the change of regime. As in most economic applications we can set $y_t = \tilde{z}_{t+k} - \tilde{z}_{t+k-m}$. That is, we assume that $\tilde{z}$ behaves differently depending on whether past changes in $\tilde{z}$ have been higher or lower than a certain threshold λ. This is a self-exciting M-TAR model with two regimes as in Enders and Granger (1998). The lag length m for the changes in $\tilde{z}$ is determined by the data as is the search for the optimal threshold λ. The parameter vectors θ_1 and θ_2 can be partitioned as

$$\theta_1 = \begin{pmatrix} \mu_1 \\ \delta_1 \\ \rho_1 \end{pmatrix}, \qquad \theta_2 = \begin{pmatrix} \mu_2 \\ \delta_2 \\ \rho_2 \end{pmatrix},$$

where μ_i is an intercept, δ_i is the parameter of the deterministic trend, and ρ_i is the autoregressive parameter with i = 1, 2. In order to search for the optimal threshold λ, Caner and Hansen (2001) follow Chan (1993) and find λ as the value of $\Delta\tilde{z}_{t+k-m}$ that minimises the residual sum of squares of the OLS estimation of (3).[13] In order to test for the existence of asymmetry in the adjustment under both regimes they test the null hypothesis $H_o : \theta_1 = \theta_2$ on the OLS estimation of (1), making use of a Wald statistic (W). The null of a unit root would imply $H_o: \rho_1 = \rho_2 = 0$. This is tested making use of another Wald statistic R1.[14] R1 is constructed as the sum of the squared values of the individual one sided t-statistics for ρ_1 and ρ_2. Finally, they also propose to choose m to minimise the

[14] R1 is the one sided Wald test for a unit root, whereas they also propose a two-sided Wald test which they call R2.

[15] See the seminal work of Balke and Fomby (1997) for the analysis of cointegration relations subject to TAR adjustment dynamics. In their case, the threshold is determined by the size of the lagged error correction mechanism.

residual sum of squares of (3). Given that the Wald test of asymmetry is a monotonic function of the residual variance, *m* is chosen as the value which maximizes the Wald test of asymmetry.

The unit root hypothesis involves testing for H_o: $\rho_1 = \rho_2 = 0$. There are two possible alternatives: H_1: $\rho_1 < 0$ *and* $\rho_2 < 0$ and

$$H_2 : \begin{cases} \rho_1 < 0 \quad and \quad \rho_2 = 0 \\ or \\ \rho_1 = 0 \quad and \quad \rho_2 < 0 \end{cases}$$

The first alternative corresponds to the stationary case, whilst the second implies stationarity in only one of the regimes, which implies overall non-stationarity but a different behaviour from the classic unit-root. Caner and Hansen (2001) develop asymptotic theory for the distribution of this unit-root test. However, for finite samples they recommend the use of bootstrapping. As the distribution of the test statistic will depend on whether or not a threshold effect exists, p-values obtained through the bootstrap are not unique. Monte Carlo experiments show that this unit root test has substantial power gains against the linear ADF test as threshold effects become larger. In order to discriminate between the two alternatives in H_2, Caner and Hansen (2001) recommend looking at the individual *t*-statistics for ρ_1 and ρ_2.

The economic interpretation of this model would be that, for certain macroeconomic variables, positive and negative shocks – or shocks above or below a certain threshold – may have different effects on the mean and speed of convergence of the data.[15]

In testing for the unit root we treat the threshold as unidentified, in which case the bootstrap is based on a linear AR model.[16] This test is implemented by choosing the estimated delay parameter *m* that minimizes the residual variance.[17] We report the Wald statistic (W_T) for the threshold effect (for nonlinearity), threshold unit root bootstrap p-values (for nonstationarity), and corresponding *t* statistics to distinguish between rejection of unit roots and nonstationarity for each series of out of sample forecast errors obtained from 16 different vintages.[18]

Table 2 about here

First, in Table 2, Columns 1 throughout 4, we report the fraction of the vintages we can reject the linearity in out of sample forecast errors for alternative monetary models under alternative deterministic specifications as regards the trend and the constant. It appears that in a significant fraction of the series we can not rule out the hypothesis of linearity. We can reject the hypothesis of linearity in the case of MY model up to 36% of the 1-quarter ahead, up to 44% of the 2-quarters ahead forecast error series estimated, in the case of MPY model up to 31% 1-quarters ahead forecast error series, at 5% significance level when the constant or constant and a trend is included in the estimation. In the case of PY model for up to 27% of the 1 or 2-quarters ahead forecast error series and in the case of P model for up to 50% of the 1 or 2-quarters ahead forecast error series we can

[16] The alternative is to treat the threshold as identified, and to base the bootstrap on simulations from a unit root TAR process. CH show Monte-Carlo evidence that suggests the unidentified threshold bootstrap test suffers from less size distortion than the identified threshold test or a test based on the asymptotic critical values for possible threshold nonlinearities.

[17] CH point out that as the Wald test W_T is a monotonic function of the residual variance, this is tantamount to choosing m as the value that maximizes W_T.

[18] Bootstrap p-values are calculated using the unidentified threshold bootstrap as described in Section 5.3 in Caner and Hansen (2001).

[19] Note, however, that this does not ensure a zero mean in the regression, as y_{t-1}^3 may have a mean that is different from zero. A proper demeaning would involve fully demeaning the left and right hand side of (4). Although this would not affect the distribution of the statistic under the null, it will affect the test results. In the empirical application we use both demeaning specifications. We implement both types of demeaning. We denote Kapetanios et al demeaning exercise as ESTAR1-t_{NL}, and full demeaning at the estimation as ESTAR2-t_{NL}. We will tabulate both set of results.

reject the hypothesis of linearity at 10% significance level when the constant and a trend is included in the estimation. It seems that it is more likely that the hypothesis of linearity is rejected against the TAR alternative when we look at shorter out of sample forecast horizons. In the same table we report the fraction of series for which we can reject the hypothesis of unit root by looking at the Wald statistic and individual t-statistics. The results are broadly consistent with linearity tests. The hypothesis of unit root is rejected in a substantial fraction of the shorter horizon forecast errors (MY model: 31% of vintages at 1 quarter ahead, and 63% of vintages at 2-quarters ahead; MPY model: 13% at the 1-quarter ahead at 5% significance level, and P model: 50% of vintages at 1 and 2-quarters ahead forecast errors at 10% significance level.). As the out of sample forecast horizon becomes longer (8 to 16 quarters) there are very few forecast error series obtained under alternative monetary model specifications for which we can reject the hypothesis of unit root. Finally, t-statistics indicate that even if one can reject the hypothesis of a unit root in a number of series, this result does not indicate that we can reject the hypothesis of nonstationarity. Indeed, t1 and t2 tests jointly taken into account indicate that it is almost impossible to rule out nonstationarity if the data generating process is assumed to be of TAR type.

For the sake of completeness we report in Figure 1 and 2 detailed results for each individual vintage.

Insert Table 4 and Figures 1 to 2 about here

We report bootstrap p-values for the unit root tests and t-values for the nonlinearity tests. In Figure 1 we plot p-values for the threshold effect, bootstrap p-values for the unit root tests and t1 and t2 tests for nonstationarity for each x-quarters ahead forecast error series (vintage) estimated with the TAR model without trend. Similarly, in Figure 2 we plot p-values for the threshold effect, bootstrap p-values for the unit root tests and t1 and t2 tests for nonstationarity for each x-quarter ahead forecast error series (vintage) estimated with the TAR model with trend. Horizontal axis represents estimated vintages starting in 1985Q1 and end in 1989Q1 (excluding 1988Q3 as mentioned before).

In Figure 1 (TAR models estimated without trend) we can confirm that the results for individual vintages for the linearity test mainly coincide with the tests for unit roots. In the case of MY model, tests for nonlinearity and unit roots reject the null hypothesis for most of the 1 and 2 quarters ahead forecast errors. Specifically, vintages for which both linearity and unit roots are rejected are between 1985Q3 and 1988Q2. P-values for both t-tests indicate that even for those series for which we could reject both linearity and unit root, we are unable to do so for the assumption of nonstationarity. Other monetary models do rather poorly in both linearity and unit root tests at 5% significance level.

Figure 2 (TAR models estimated with trend) reports that, with the exception of P model for which we are able to reject the null of linearity and unit roots at 1 and 2 quarters ahead forecast errors for vintages ranging from 1986Q3 to 1987Q3, we are unable to detect TAR form of nonlinear mean reversion in most of the other model/vintage combination.

In sum, TAR unit root tests results suggest that real time monetary aggregates and real output provide quite valuable information about short term forecastability of exchange rates when are used in the monetary estimations covering 1985Q3 and 1988Q2 vintages.

As a next step we assess the implications of another nonlinear dynamic adjustment specification in the out of sample forecast errors. ESTAR model is considered to be more plausible type of nonlinear dynamic adjustment process for exchange rates in the long term.

ESTAR Unit Root Tests (*Kapetanios, Shin and Snel (2003))****:*** ESTAR model has been very popular recently. As argued earlier transaction cost arguments or existence of heterogeneous traders/beliefs in the financial markets may trigger a smooth asymmetric adjustment of the exchange rate towards its linear fundamental equilibrium. As discussed in Granger and Teräsvirta (1993) in general and Taylor and Peel (2001) and Kilian and Taylor (2003) for the monetary exchange rate models, we postulate a smooth transition autoregressive model of the form

$$\Delta\tilde{z}_{t+k} = \rho_1\tilde{z}_{t+k-1} + \rho_2\tilde{z}_{t+k-1}G(y_t;\phi,\lambda) + \varepsilon_t\ ,$$

(4)

where G is a transition function, ε_t is an $iid(0, \sigma^2)$ error, y_t is a state variable, ϕ is the speed of transition variable, and λ is a threshold. Because of the particularly interesting properties of ESTAR models for economic applications, Kapetanios et al (2003), focus on tests for a unit root when the DGP follows an ESTAR process under the alternative. When we set the state variable as, $\mathrm{y_t} = \tilde{z}_{t+k\text{-d}}$ it represents a self-exciting ESTAR model. In this case (4) becomes:

$$\Delta\tilde{z}_{t+k} = \rho_1\tilde{z}_{t+k\text{-}1} + \rho_2\tilde{z}_{t+k\text{-}1}[1-\exp(-\phi(\tilde{z}_{t+k\text{-d}}-\lambda)^2] + \varepsilon_t$$

Transition function $[1-\exp(-\phi(\tilde{z}_{t+k\text{-d}}-\lambda)^2]$ determines the degree of nonlinearity as a function of the speed of adjustment coefficient ϕ. In line with most of the literature we set the delay parameter d equal to 1. (See for instance Teräsvirta (1994), or Taylor, Peel and Sarno (2001)).

As Kapetanios et al. (2003) assume that z_t is a mean-zero stochastic process, one can set λ = 0. This makes $G = 1-\exp\{-\phi\tilde{z}^2_{t+k\text{-}1}\}$. As $z_{t-1} \to \pm\infty$, $G \to 1$, and as $\tilde{z}_{t+k\text{-}1}$ gets close to zero $G \to 0$. Hence, the process shows three regimes, a middle regime when $\tilde{z}_{t+k\text{-}1}$ is close to zero and two symmetric outer regimes when $\tilde{z}_{t+k\text{-}1}$ becomes large (either positive or negative). The smoothness of the transition between these regimes depends on the parameter ϕ.

Kapetanios et al. (2003) further impose the assumption that $\rho_1 = 0$. This assumption can be justified on the grounds of transaction costs arguments or heterogeneity in beliefs as discussed earlier. The variable displays a mean reverting behaviour towards an attractor when it is sufficiently far away from it, but a random walk representation in the neighbourhood of the attractor. In this case, we have that

$$\Delta\tilde{z}_{t+k} = \rho_2 \tilde{z}_{t+k\text{-}1}[1-\exp(-\phi\tilde{z}^2_{t+k\text{-}1})] + \varepsilon_t \qquad (5)$$

And the test for the *joint* null hypothesis of linearity and a unit root can be achieved by testing H_0: $\phi = 0$ against H_1: $\phi > 0$. Using a first order Taylor series approximation to (5), one can obtain

$$\Delta\tilde{z}_{t+k} = \varphi\tilde{z}^3_{t+k-1} + error \qquad (6)$$

The unit root test is based on the t-statistic for the null $\varphi = 0$ against the alternative $\varphi < 0$ from the OLS estimate of φ ($\hat{\varphi}$). The asymptotic distribution of this test (t_{NL}) is non-standard and Kapetanios et al. (2003) derive it and provide asymptotic critical values. We refer for the asymptotic critical values of the t_{NL} to Kapetanios et al.(2003) Table 1.

When the process z_t is not mean zero, they propose the use of transformations of the data. For the case of a non-zero mean, i.e. $x_t = \mu + \tilde{z}_{t+k}$, they propose the use of de-meaned data $\tilde{z}^*_{t+k} = x_{t+k} - \bar{x}$, where $\bar{x}$ is the sample mean. For the case of a non-zero mean and a non-zero deterministic trend, i.e. $x_{t+k} = \mu + \delta t + \tilde{z}_{t+k}$ they propose the use of the de-meaned and de-trended data $\tilde{z}^*_{t+k} = x_{t+k} - \hat{\mu} - \hat{\delta}t$, where $\hat{\mu}$ and $\hat{\delta}$ are the OLS estimators of μ and δ. This procedure allows carrying out the test using (6) with the de-meaned/de-trended data.[19] In line with the suggestion of Kapetanios et al. (2003) we append to equation (6) one or four autoregressive lags based on Akaike Information Criteria.

Insert Table 3 about here

We implement the ESTAR joint linearity and unit root test for 16 available vintages in real time. In Table 3 we report percentage of real time vintages for which we can reject the hypothesis of unit root together with linearity, therefore conclude in favour or nonlinear mean reversion.

A quick inspection of Table 3 suggests that, first, several out of sample forecast error series over different horizons obtained from estimations from 16 vintages of real time dataset do not reveal much nonlinear mean reversion at shorter horizons. In the case of MPY, PY and MY models with or without trend we do not detect significant ESTAR type mean reversion in short term (1 to 4-quarters ahead) forecast errors. Only in the case of the P model at 4-quarters forecast horizon we find some exchange rate predictability (18.8% of the series at 5% significance level).

In the long term (16-quarters), however, in the case of MY model without trend, however, about 18.8% of the forecast errors series seem to exhibit ESTAR form of mean reversion at 5% significance level. When we implement the same test for the P model (real exchange rate model) we find that about half of the forecast error series within 16-quarters are mean reverting at 5% significance level. This corroborates to some extent the findings of Kilian and Taylor (2003) and Taylor et al. (2001) as regards the smooth nonlinear mean reversion of real exchange rates, in our case only being true for only half of the real exchange rate models using real time vintages of fundamentals.

Insert Figure 3 and Table 5 about here

Next we report performance of individual vintages with the ESTAR specification. In Figure 3 we plot the t_{NL}-statistics for each individual series estimated. Note again that horizontal axis represents vintages that start in 1985Q1 and end in 1989Q1 (excluding August 1988Q3). As we observe P model is useful in forecasting exchange rates at 4-quarters forecast horizon in 1985Q1 to 1985Q3 vintages and at 16-quarters forecast horizon in 1985Q2, 1985Q3 and 1986Q1 to 1987Q2 vintages, whereas MY model is useful in forecasting 1985Q1, 1985Q2 and 1989Q1 vintages.[20]

5. Conclusions

In this paper we examine the real time out of sample predictive power of fundamentals based Pound Sterling/US Dollar exchange models with nonlinear adjustments in forecast errors. We extend the analysis of Faust et al. (2003) in the direction of nonlinear mean reversion and Kilian and Taylor (2003) in the direction of accounting for real time revisions in datasets of fundamentals.

We claim that in several instances, real time fundamental equilibrium values of exchange rates may be determined in a linear fashion, whereas adjustment towards the fundamentals driven equilibrium values may take a discrete or smooth nonlinear form. Revisions in fundamentals, particularly in the US and UK monetary aggregates and real output, seem to matter mainly for short term forecastability of exchange rates. Our evidence suggests that in some real time vintages even short term forecastability can be found in the form of discrete nonlinear adjustment while long term forecastability may be present in the form of smooth nonlinear adjustment towards fundamentals determined equilibrium value of exchange rates.

[20] We have also implemented the same series of tests with the use of period average instead of end of period Pound Sterling /US Dollar exchange rates. The percentages of vintages that exhibit nonlinear mean reversion under various forecast horizons are much higher in this case. Results are available upon request.

References:

Aruoba, B. (2005), Data Revisions are not Well-behaved, mimeo. University of Maryland.

Balke, N. S. and Fomby, T.B. (1997) Threshold Cointegration*, International Economic Review*, **38**, pp. 627-45.

Berkowitz, J., and Giorgianni, L., (2001), Long-horizon Exchange Rate Predictability?, *Review of Economics and Statistics, pp.*.

Caner, H., and Hansen, B., (2001), Threshold Autoregression with a Unit Root, *Econometrica*, **69**, pp. 1555-96.

Chen, J., and Mark, N. (1995) Alternative Long Horizon Exchange Rate Predictors, *International Journal of Finance & Economics*, **1,** pp. 229-250.

Cheung, Y.W. and Chinn, M.D., (2001) Currency Traders and Exchange Rate Dynamics: A Survey of the US Market, *Journal of International Money and Finance*, **20**, pp. 439-471.

Chortareas, G. and Kapetanios, G. (2004), The Yen Real Exchange Rate May Be Stationary After All: Evidence from Non-linear Unit-roots Tests, *Oxford Bulletin of Economics and Statistics*, **66**, pp. 113-121.

Coakley, J. and Fuertes, A.M. (2001), Border Costs and Real Exchange Rate Dynamics in Europe, *Journal of Policy Modeling*, **23**, pp.669-76.

Croushore, D. and Stark, T., (2003), A Real-Time Data Set for Macroeconomists: Does the Data Vintage Matter? *Review of Economics and Statistics,* **85(3)**, pp. 605-617.

De Grauwe, P., and Dewachter, H., (1993), Chaos in the Dornbusch Model: The Role of Fundamentalists and Chartists, *Open Economies Review,* **4**, pp. 351-379

De Grauwe, P. and Grimaldi, M., (2005), *The Exchange Rate in a Behavioural Finance Framework*, Princeton University Press.

Diebold, F. and Mariano, R. (1995) Comparing Predictive Accuracy, *Journal of Business and Economic Statistics*, **13**, pp. 253-63.

Enders, W. and Granger, C.W.J., (1998), Unit-Root Tests and Asymmetric Adjustment with an Example Using the Term Structure of Interest Rates*, Journal of Business & Economic Statistics*, **16**, pp. 304-311.

Faust, J., Rogers J.H. and Wright, J., (2005), News and Noise in G-7 GDP Announcements, *Journal of Money, Credit, and Banking*, **37**, pp. 403-19.

Faust, J., Rogers J.H. and Wright, J., (2003), Exchange Rate Forecasting: The Errors We've Really Made, *Journal of International Economics,* **60**, pp. 35-59.

Granger, C.W.J. and Teräsvirta, T., (1993), *Modelling Nonlinear Economic Relationships,* Oxford University Press, Oxford.

Kapetanios, G., Shin, Y., and Snell, A., (2003), Testing for a Unit Root in the Nonlinear STAR framework, *Journal of Econometrics*, **112**, pp. 359-79.

Kilian, L., (1999), Exchange Rates and Monetary Fundamentals: What Do We Learn from Long-Horizon Regressions?, *Journal of Applied Econometrics,* **14**, pp. 491-510.

Kilian, L., and Taylor, M. P., (2003) Why is It So Difficult to Beat the Random Walk Forecast of Exchange Rates?," *Journal of International Economics*, **60**, pp. 85-107.

Kindleberger, C., (1989), *Manias, Panics and Crashes: A History of Financial Crisis*, Macmillan, London.

Lux, T., (1995), Herd Behaviour, Bubbles and Crashes, *Economic Journal*, **105**, pp. 881-96.

Mankiw, N.G. and Shapiro, M.D. (1987). News or Noise? An Analysis of GNP Revisions, NBER Working Paper No. 1339, Cambridge MA.

Mankiw, N.G., Runkle, D.E. and Shapiro, M.D. (1984) Are Preliminary Announcements of the Money Stock Rational Forecasts? *Journal of Monetary Economics* **14**, pp. 15-27.

Mark, N., (1995), Exchange Rates and Fundamentals: Evidence on Long Horizon Predictability, *American Economic Review*, **85**, pp.201-218.

Marsh, I., Cheung, Y.W., and Chinn, M.D., (2004), How Do UK-based Foreign Exchange Dealers Think their Market Operates?, *International Journal of Finance and Economics*, **9**, pp 289-306.

Michael, P., Nobay, A.R. and Peel, D.A., (1997), Transactions Costs and Nonlinear Adjustment in Real Exchange Rates: an Empirical Investigation, *Journal of Political Economy,* **105**, pp. 862–879.

Neely, C, and Sarno, L., (2002), How Well do Monetary Fundamentals Forecast Exchange Rates?, *Review*, Federal Reserve Bank of St. Louis, issue Sep, pp. 51-74.

Neftci, S.N. (1984), Are Economic Time Series Asymmetric over the Business Cycle?, *Journal of Political Economy*, **92**, pages 307-28.

Orphanides, A., (2001), Monetary Policy Rules Based on Real-Time Data, *American Economic Review,* **91**, pp. 964-985.

Orphanides, A., (2003), Monetary Policy Evaluation with Noisy Information, *Journal of Monetary Economics,* **50**, pp. 605-631

Orphanides, A. and van Norden, S., (2002), The Unreliability of Output Gap Estimates in Real Time, *Review of Economics and Statistics,* **84(4)**, pp. 569-583.

Sercu, P., Uppal, R. and Van Hulle, C., (1995), The Exchange Rate in the Presence of Transactions Costs: Implications for Tests of Purchasing Power Parity. *Journal of Finance,* **50** 4, pp. 1309–1319.

Shiller, R.J., (1984), Stock Prices and Social Dynamics, Brookings Papers in Economic Activity, **2**, pp.457-510.

Stockman, A., (1987), The Equilibrium Approach to Exchange Rates, *Economic Review*, Federal Reserve Bank of Richmond, pp. 12-31.

Taylor, M.P., (1995), The Economics of Exchange Rates, *Journal of Economic Literature*, **33(1)**, pp. 13-47.

Taylor, M.P. and Peel, D.A., (2000), Nonlinear Adjustment, Long-run Equilibrium and Exchange Rate Fundamentals, *Journal of International Money and Finance*, **19**, pp. 33-53.

Taylor, M.P., Peel, D.A., and Sarno, L., (2001), Nonlinear Mean-Reversion in Real Exchange Rates: Toward a Solution To the Purchasing Power Parity Puzzles, *International Economic Review*, **42**, pp. 1015-1042.

Teräsvirta, T., (1994), Specification, Estimation and Evaluation of Smooth Transition Autoregressive Models, *Journal of the American Statistical Association* **89**, pp. 208–218.

Tong, H., (1990), *Nonlinear Time Series: A Dynamical System Approach* Clarendon Press, Oxford.

Appendix A: Real Time Dataset

	Variable	Definition	Base Year Changes	Source
UK	Real Output (GDP)	Seasonally adjusted	Sep 1983, Sep 1988	Economic Trends and Economic Trends Annual Supplement http://www.bankofengland.co.uk/statistics/gdpdatabase/
	Money Supply (£M3)	Seasonally adjusted, end of period		Economic Trends and Economic Trends Annual Supplement For details in revisions see http://www.bankofengland.co.uk/statistics/ms/articles/art2jul03.doc
	Prices	Retail Price Index	Nov 1987, Nov 1988	Economic Trends
US	Real Output (GNP)	Seasonally Adjusted, fixed-weight	1986Q1	Federal Reserve Bank of Philadelphia http://www.phil.frb.org/econ/forecast/reaindex.html
	Money Supply (M2)	Seasonally Adjusted, quarterly average of monthly data		Federal Reserve Bank of Philadelphia
	Prices	Consumer Price Index	May 1983	IMF/IFS
Exchange Rate	Pound Sterling/US Dollar exchange rate	End of period		IMF/IFS

Table 1: Data Revisions (in % change)

	UK Money Supply					US Money Supply					UK Output					US Output				
	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16
1970.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.08	-0.31	0.48	0.38	-	-	-	0.00	0.06	0.06	0.06	-
1970.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	-0.43	0.37	0.20	-	-	-	0.00	0.18	0.18	0.18	-
1971.1	0.00	0.00	1.18	1.18	1.18	0.00	0.00	-0.03	0.01	-0.44	0.37	0.25	-	-	-	0.00	0.44	0.44	0.68	-
1971.2	0.00	0.00	0.55	0.55	0.55	0.00	0.00	-0.04	-0.04	-0.49	0.34	0.20	-	-	-	0.00	0.34	0.34	0.57	-
1971.3	0.00	0.00	0.37	0.37	0.37	0.00	0.00	-0.15	-0.10	-0.56	0.60	0.61	-	-	-	0.00	0.59	0.59	0.63	-
1971.4	0.00	0.00	0.20	0.20	0.20	0.00	0.00	-0.17	-0.15	-0.52	0.51	0.47	-	-	-	0.00	0.60	0.60	0.61	-
1972.1	0.00	0.00	0.96	0.96	0.96	0.00	0.00	-0.20	-0.21	-0.34	0.89	0.82	-	-	-	0.00	0.20	0.20	0.57	-
1972.2	0.00	0.00	0.40	0.40	0.40	0.00	0.00	-0.26	-0.20	-0.32	0.69	0.31	-	-	-	0.00	0.22	0.22	0.34	-
1972.3	0.00	0.00	0.39	0.39	0.39	0.00	0.00	-0.10	-0.11	-0.18	0.62	0.39	-	-	-	0.00	0.08	0.08	0.25	-
1972.4	0.00	0.00	0.24	0.24	0.24	0.00	0.00	0.06	0.08	0.01	-0.47	-	-	-	-	-0.10	-0.01	-0.01	0.22	-
1973.1	0.00	0.00	-0.08	0.04	0.04	0.00	0.00	0.35	0.44	0.43	-	-	-	-	-	0.27	0.27	0.27	0.69	-
1973.2	0.00	0.00	0.11	0.47	0.47	0.00	0.57	0.59	0.64	0.49	0.64	0.48	0.72	1.39	3.16	-0.04	-0.04	0.34	0.34	-
1973.3	0.00	0.00	-0.07	0.75	0.75	0.79	0.79	0.82	0.84	0.71	-0.72	-0.75	-0.61	-0.34	0.87	-0.04	-0.04	-0.10	-0.10	-
1973.4	0.00	0.00	0.51	0.22	0.22	0.00	0.14	0.12	0.02	0.02	-0.20	0.51	0.91	0.63	1.84	0.06	0.19	0.19	-	-
1974.1	0.00	0.00	0.34	0.25	1.11	0.32	0.20	0.23	0.14	0.24	0.49	0.66	0.74	0.89	1.21	-0.18	-0.18	-0.18	-	-
1974.2	0.00	0.00	0.12	0.15	0.55	-0.28	-0.17	-0.14	-0.44	-0.42	0.18	0.46	0.90	1.84	-	-0.11	-0.11	-0.11	-	-
1974.3	0.00	0.00	-0.09	-0.03	-0.12	0.06	0.09	0.05	-0.16	-0.23	0.98	1.04	1.71	1.52	-	0.24	0.24	0.24	-	-
1974.4	0.00	0.00	0.66	0.29	-0.37	0.06	-0.09	-0.23	-0.23	-0.27	0.35	-0.40	-0.52	-0.09	-	0.04	0.04	-	-	-
1975.1	0.00	0.00	-0.26	-0.23	0.77	-0.13	-0.31	-0.48	-0.46	-0.32	-1.29	-1.87	-2.16	-1.28	-	-0.29	-0.29	-	-	-
1975.2	0.00	0.00	-0.14	-0.64	-0.28	-0.21	-0.64	-0.64	-0.65	-0.63	-0.56	-1.36	-0.09	0.26	-	0.54	-	-	-	-
1975.3	0.00	0.00	0.05	-0.43	-0.08	-0.48	-0.48	-0.48	-0.50	-0.50	-0.80	-0.61	-0.01	-0.12	-	-	-	-	-	-
1975.4	0.00	0.00	0.54	0.35	-0.40	0.00	0.08	0.08	0.08	-	0.45	0.64	0.09	-1.36	-	-0.10	0.15	0.15	1.02	0.86
1976.1	0.00	0.00	0.13	0.05	0.82	0.22	0.14	0.17	0.31	-	-0.44	-0.27	-0.86	-1.27	-	0.64	0.64	0.64	1.42	1.70
1976.2	0.00	0.00	0.18	-0.41	-0.05	-0.21	-0.21	-0.23	-0.23	-	0.37	0.64	2.04	-	-	0.02	0.02	0.94	0.66	0.61
1976.3	0.05	0.02	0.00	-0.37	-0.37	0.00	-0.03	-0.03	-0.01	-	-0.57	-0.60	0.70	-	-	0.00	0.00	0.90	0.34	0.39
1976.4	-0.02	0.10	0.30	0.27	-0.20	-0.03	0.05	0.05	0.11	-	-0.15	0.17	0.32	-	-	-0.09	0.46	0.46	0.20	2.65
1977.1	-0.02	0.25	0.25	0.64	0.44	0.21	0.21	0.37	0.52	-	0.13	-0.03	0.75	-	-	1.10	1.10	1.10	0.76	3.79
1977.2	-0.14	-0.14	-0.12	-0.24	-0.62	0.00	0.00	0.11	0.26	-	0.11	0.25	-	-	-	-0.07	-0.07	-0.46	-0.03	2.39
1977.3	-0.07	-0.07	-0.42	-0.30	-0.14	0.00	0.02	0.19	0.21	-	1.12	1.29	-	-	-	0.31	0.31	0.05	0.80	3.17
1977.4	0.00	-0.04	0.00	-0.72	-0.02	0.12	0.17	0.29	-	-	0.57	-	-	-	-	-0.09	-0.51	-0.51	-0.01	2.21
1978.1	0.11	0.39	0.41	0.45	0.77	0.17	0.29	0.31	-	-	-	-	-	-	-	-0.30	-0.30	-0.30	0.70	3.24
1978.2	0.02	0.00	0.04	0.19	0.42	0.03	0.17	0.17	-	-	-0.06	0.32	0.60	2.32	2.31	0.29	0.29	1.20	1.20	4.24
1978.3	0.12	0.18	0.18	0.79	0.31	0.38	0.38	0.34	-	-	0.42	0.46	0.43	1.30	1.21	-0.21	-0.21	0.93	0.93	3.91
1978.4	0.06	0.06	-0.53	-0.08	0.04	0.00	-0.07	-	-	-	0.49	1.26	0.71	1.67	2.16	0.18	1.02	1.02	3.80	3.98
1979.1	-0.02	0.10	0.13	0.50	0.79	-0.04	-0.04	-	-	-	-0.13	-0.15	1.60	2.09	2.43	0.94	0.94	0.94	4.42	3.90
1979.2	0.24	0.24	0.28	0.54	0.18	0.00	-	-	-	-	1.53	2.79	4.65	4.36	-	0.25	0.25	0.25	3.85	3.55
1979.3	0.00	0.04	0.88	0.41	0.11	-	-	-	-	-	0.21	1.89	2.60	2.90	-	0.17	0.17	0.17	4.01	3.90
1979.4	0.02	0.02	-0.12	0.22	-2.44	0.01	0.14	0.17	-0.19	-1.51	5.10	6.58	6.62	6.96	-	0.13	0.13	3.63	3.63	3.54
1980.1	0.00	0.61	0.61	1.15	-1.17	0.11	0.11	0.29	-0.18	-1.57	0.89	1.74	1.79	1.83	-	0.03	0.03	4.00	4.00	3.61
1980.2	-0.05	-0.05	-0.14	0.42	-1.73	-0.01	0.08	0.28	-0.36	-1.93	0.81	0.25	0.21	0.77	-	-0.16	3.72	3.72	3.33	3.59
1980.3	-0.02	-0.08	0.67	0.47	-1.45	0.19	0.20	0.25	-0.71	-2.38	-0.27	-0.05	0.59	0.95	-	4.23	4.23	4.23	3.66	3.69
1980.4	0.13	0.16	0.83	0.58	-2.01	-0.23	-0.18	-0.97	-2.43	-2.45	0.08	1.13	-0.03	0.72	-	-0.30	-0.30	-0.30	-0.72	-0.82
1981.1	0.01	0.52	0.52	0.84	-1.89	0.02	0.02	-0.97	-2.58	-2.57	0.09	-0.13	-0.04	0.26	-	0.48	0.48	0.48	-0.09	0.28
1981.2	0.27	0.27	0.27	0.08	-2.31	0.00	-0.66	-0.66	-2.76	-2.65	0.26	-0.05	-	-	-	0.09	0.09	-0.46	0.23	0.17
1981.3	0.00	0.00	-0.31	-0.37	-2.35	-0.37	-0.37	-0.36	-2.06	-2.37	-0.32	-0.06	-	-	-	0.50	0.50	0.15	1.17	0.92
1981.4	0.03	0.01	-0.29	-2.59	-2.22	0.01	0.02	-1.51	-1.51	-1.73	-0.27	-0.71	-0.69	-	-	0.19	-0.37	-0.37	0.76	-
1982.1	-0.19	0.40	0.34	-2.11	-2.09	0.02	0.02	-1.77	-1.69	-1.79	0.30	0.30	0.01	-	-	-0.87	-0.87	-0.87	0.15	-
1982.2	0.27	0.25	-0.08	-1.92	-2.21	0.00	-2.39	-2.39	-2.23	-2.38	-0.25	-0.61	-	-	-	0.11	0.11	0.85	0.25	-
1982.3	-0.01	-0.08	0.19	-1.71	-2.66	-2.10	-2.10	-2.10	-2.30	-2.54	0.19	0.54	-	-	-	-0.01	-0.01	0.30	-0.28	-
1982.4	-0.04	-0.31	-2.69	-2.67	-3.41	0.04	0.04	0.04	-0.22	-0.26	-0.08	-	-	-	-	0.37	0.61	0.61	0.48	-
1983.1	-0.83	-0.37	-2.44	-1.79	-2.65	0.13	0.13	0.27	-0.07	-0.18	-	-	-	-	-	0.11	0.11	0.11	0.17	-
1983.2	0.75	-1.77	-1.77	-1.34	-2.11	0.00	0.00	0.24	-0.12	-0.24	0.52	-1.10	1.49	0.81	1.18	0.24	0.24	0.22	0.22	-
1983.3	-2.19	-2.22	-2.07	-1.69	-2.46	0.00	0.02	0.02	-0.17	-0.25	-2.61	0.09	1.79	1.43	1.74	-0.06	-0.06	-0.27	-0.27	-
1983.4	0.04	0.00	0.00	0.66	-0.68	0.38	0.39	0.17	0.08	0.02	2.66	3.44	2.57	2.48	2.73	0.13	0.14	0.14	-	-
1984.1	-0.10	-0.37	0.13	0.18	-1.35	0.03	0.03	-0.14	-0.22	-0.20	1.19	1.16	0.18	0.71	-	0.41	0.41	0.41	-	-
1984.2	-0.69	-0.68	-0.25	-0.21	-1.30	0.00	-0.12	-0.12	-0.09	-0.17	0.02	-0.75	-0.56	-0.15	-	-0.09	-0.09	-0.09	-	-
1984.3	-0.01	0.41	0.28	-0.40	-1.41	0.04	0.04	0.04	0.01	-0.15	-0.30	-0.15	0.56	0.83	-	-0.27	-0.27	-0.27	-	-
1984.4	0.45	0.45	0.62	-0.29	-	-0.01	0.02	0.14	-0.03	-0.12	-0.12	-0.12	-0.26	0.33	-	0.08	0.08	-	-	-
1985.1	-0.02	-0.26	-0.19	-1.14	-	0.01	0.01	0.03	-0.04	-	0.01	0.05	0.22	1.51	-	-0.27	-0.27	-	-	-
1985.2	-0.62	-0.45	-0.45	-0.55	-	0.01	0.28	0.28	0.13	-	-0.09	0.16	0.96	1.06	-	0.04	-	-	-	-
1985.3	0.26	0.26	-0.48	-1.34	-	0.10	0.11	0.12	-0.05	-	-0.14	0.88	0.65	1.37	-	-	-	-	-	-
1985.4	-0.01	-0.01	-0.77	-1.63	-	0.04	0.04	0.03	0.03	-	-0.36	0.02	0.10	0.22	-	-0.39	0.48	0.48	1.27	-
1986.1	0.04	0.07	0.06	-1.14	-	-0.01	0.03	0.24	0.26	-	0.77	0.69	1.22	1.52	-	1.01	1.01	1.01	2.20	-
1986.2	0.78	0.73	0.06	-0.06	-	0.06	0.01	0.01	0.24	-	0.12	-0.09	0.61	-	-	-0.12	-0.12	1.06	1.25	-
1986.3	-0.09	-0.09	0.06	-1.40	-	-0.18	-0.18	-0.17	0.11	-	0.00	0.23	0.31	-	-	0.08	0.08	0.94	1.03	-
1986.4	0.09	0.11	0.06	0.24	-	0.04	0.05	0.08	0.39	-	0.43	0.86	2.08	-	-	-0.17	0.79	0.79	0.87	-
1987.1	0.14	0.11	0.06	-	-	-0.01	0.04	0.26	-	-	0.06	-0.17	0.71	-	-	0.99	0.99	0.99	-	-
1987.2	0.04	-0.43	0.06	-	-	0.04	0.04	0.35	-	-	0.22	0.39	-	-	-	-0.03	-0.03	0.70	-	-
1987.3	-0.20	-0.11	0.06	-	-	0.03	0.29	0.28	-	-	-0.38	-	-	-	-	0.12	0.12	0.89	-	-
1987.4	0.07	-0.19	0.06	-	-	0.16	0.17	0.45	-	-	-0.02	-	-	-	-	0.15	1.24	1.24	-	-
1988.1	-0.25	-0.28	0.06	-	-	0.00	0.00	-	-	-	-	-	-	-	-	1.37	1.37	-	-	-
1988.2	0.00	0.01	0.06	-	-	-0.02	-0.08	-	-	-	0.00	2.62	-	-	-	-0.03	-0.03	-	-	-
1988.3	-0.28	-	0.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average	-0.03	-0.03	0.01	-0.19	-0.53	-0.18	-0.23	-0.31	-0.46	-0.67	0.24	0.43	0.73	1.06	1.51	0.15	0.29	0.52	0.94	2.48
St. Dev	0.34	0.41	0.65	0.89	1.20	0.30	0.44	0.57	0.82	0.96	0.90	1.19	1.41	1.53	0.73	0.61	0.77	1.00	1.33	1.55

Note: Note that first 1970Q3 data point is obtained from the first real time vintage that we possess dating 1977Q1. That means first revision that we report for 1970Q3 in column 2 is based on the second vintage that we possess dating 1977Q2 and so on.

Table 2: TAR Estimation: Percentage of the vintages that reject the null hypothesis of unit root

	linearity				unit root												*# of vintages used*	
	Wald test for threshold effect				One-sided Wald test for unit root				t1 test for unit root				t2 test for unit root					
	constant		constant and trend		constant		constant and trend		constant		constant and trend		constant		constant and trend		*constant*	*constant and trend*
	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%		
MY Model																		
1-quarter	25%	69%	36%	64%	31%	81%	0%	0%	94%	94%	0%	9%	0%	0%	0%	0%	*16*	*11*
2-quarters	44%	75%	36%	64%	63%	94%	0%	0%	94%	94%	0%	9%	0%	0%	0%	0%	*16*	*11*
4-quarters	0%	0%	0%	0%	0%	0%	0%	0%	6%	38%	0%	9%	0%	0%	0%	0%	*16*	*11*
8-quarters	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	*16*	*10*
16-quarters	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	*9*	*2*
MPY Model																		
1-quarter	31%	31%	18%	36%	13%	25%	9%	9%	19%	25%	18%	18%	13%	13%	0%	18%	*16*	*11*
2-quarters	0%	13%	0%	10%	0%	13%	0%	0%	38%	69%	40%	80%	0%	0%	0%	0%	*16*	*10*
4-quarters	0%	0%	0%	0%	0%	6%	0%	0%	25%	69%	0%	11%	0%	0%	0%	0%	*16*	*9*
8-quarters	0%	0%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	0%	0%	0%	0%	*15*	*5*
16-quarters	0%	11%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	*9*	*1*
PY Model																		
1-quarter	0%	0%	0%	27%	0%	0%	0%	0%	25%	38%	64%	91%	0%	0%	0%	0%	*16*	*11*
2-quarters	0%	0%	0%	27%	0%	0%	0%	0%	6%	25%	36%	91%	0%	0%	0%	0%	*16*	*11*
4-quarters	0%	0%	0%	0%	0%	0%	0%	0%	0%	31%	0%	0%	0%	0%	0%	0%	*16*	*10*
8-quarters	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	*16*	*4*
16-quarters	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	*9*	*1*
P Model																		
1-quarter	0%	0%	0%	50%	0%	0%	0%	50%	6%	63%	50%	60%	0%	0%	0%	0%	16	10
2-quarters	0%	0%	0%	50%	0%	0%	0%	50%	0%	0%	50%	60%	0%	0%	0%	0%	16	10
4-quarters	0%	0%	0%	13%	0%	0%	0%	13%	0%	0%	0%	50%	0%	0%	0%	0%	16	8
8-quarters	0%	0%	0%	0%	0%	0%	0%	17%	0%	0%	0%	33%	0%	0%	0%	0%	16	6
16-quarters	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	30%	0%	0%	10	1

Table 3. ESTAR Estimation: Percentage of the vintages that reject the null hypothesis of unit root

	ESTAR1-t_{NL}				ESTAR2-t_{NL}			
	Constant		Constant and Trend		Constant		Constant and Trend	
	5%	10%	5%	10%	5%	10%	5%	10%
MY Model								
1-quarter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2-quarters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4-quarters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8-quarters	0.0	6.3	0.0	0.0	0.0	0.0	6.3	18.8
16-quarters	18.8	18.8	12.5	18.8	12.5	12.5	12.5	12.5
MPY Model								
1-quarter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2-quarters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3
4-quarters	0.0	0.0	0.0	12.5	0.0	0.0	12.5	25.0
8-quarters	0.0	6.3	0.0	6.3	0.0	0.0	12.5	18.8
16-quarters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PY Model								
1-quarter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2-quarters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4-quarters	0.0	0.0	0.0	6.3	0.0	0.0	6.3	25.0
8-quarters	0.0	0.0	0.0	18.8	0.0	0.0	6.3	18.8
16-quarters	0.0	0.0	0.0	6.3	0.0	0.0	0.0	6.3
P Model								
1-quarter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2-quarters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4-quarters	18.8	25.0	0.0	0.0	12.5	12.5	0.0	0.0
8-quarters	0.0	6.3	0.0	0.0	0.0	6.3	0.0	0.0
16-quarters	50.0	50.0	50.0	50.0	6.3	6.3	0.0	12.5

Table4. TAR Unit Root Test: Vintages that reject the null hypothesis of unit root

MY Model

Wald test for Linearity

Vintage /	Constant					Constant and Trend				
Forec. Hor.	1	2	4	8	16	1	2	4	8	16
1985Q1					X	X	X	X	X	X
1985Q2					X	X	X	X	X	X
1985Q3	**	**			X	X	X	X	X	X
1985Q4	**	**			X	X	X	X	X	X
1986Q1	*	**			X	X	X	X	X	X
1986Q2	**	**			X	**	**		X	X
1986Q3	*	**			X	**	**			X
1986Q4	*	**				**	**			X
1987Q1	**	**				**	**			X
1987Q2	*	*				*	*			X
1987Q3	*	*				*	*			X
1987Q4	*	*				*	*			X
1988Q1	*	*								X
1988Q2		*								X
1988Q4										
1989Q1										

1-Sided Wald Test for Unit Root

Vintage /	Constant					Constant and Trend				
Forec. Hor.	1	2	4	8	16	1	2	4	8	16
1985Q1		*			X	X	X	X	X	X
1985Q2		*			X	X	X	X	X	X
1985Q3	**	**			X	X	X	X	X	X
1985Q4	**	**			X	X	X	X	X	X
1986Q1	**	**			X	X	X	X	X	X
1986Q2	**	**			X				X	X
1986Q3	*	**			X					X
1986Q4	*	**								X
1987Q1	**	**								X
1987Q2	*	**								X
1987Q3	*	**								X
1987Q4	*	**								X
1988Q1	*	*								X
1988Q2	*	*								X
1988Q4	*	*								
1989Q1										

t1 test for unit root

Vintage /	Constant					Constant and Trend				
Forec. Hor.	1	2	4	8	16	1	2	4	8	16
1985Q1	**	**	*		X	X	X	X	X	X
1985Q2	**	**			X	X	X	X	X	X
1985Q3	**	**	*		X	X	X	X	X	X
1985Q4	**	**	*		X	X	X	X	X	X
1986Q1	**	**	*		X	X	X	X	X	X
1986Q2	**	**	**		X				X	X
1986Q3	**	**			X					X
1986Q4	**	**				*	*			X
1987Q1	**	**						*		X
1987Q2	**	**								X
1987Q3	**	**								X
1987Q4	**	**								X
1988Q1	**	**								X
1988Q2	**	**								X
1988Q4	**	**	*							
1989Q1										

t2 test for Unit Root

Vintage /	Constant					Constant and Trend				
Forec. Hor.	1	2	4	8	16	1	2	4	8	16
1985Q1					X	X	X	X	X	X
1985Q2					X	X	X	X	X	X
1985Q3					X	X	X	X	X	X
1985Q4					X	X	X	X	X	X
1986Q1					X	X	X	X	X	X
1986Q2					X				X	X
1986Q3					X					X
1986Q4										X
1987Q1										X
1987Q2										X
1987Q3										X
1987Q4										X
1988Q1										X
1988Q2										X
1988Q4										
1989Q1										

MPY Model

Wald test for Linearity

Vintage /	Constant					Constant and Trend				
Forec. Hor.	1	2	4	8	16	1	2	4	8	16
1985Q1	**	*		X	X	X	X	X	X	X
1985Q2	**	*			X	X	X	X	X	X
1985Q3					X	X	X	X	X	X
1985Q4					X	X	X	X	X	X
1986Q1					X	X	X	X	X	X
1986Q2					X	*	X	X	X	X
1986Q3					X			X	X	X
1986Q4					*				X	X
1987Q1							*		X	X
1987Q2									X	X
1987Q3									X	X
1987Q4										X
1988Q1	**					**				X
1988Q2	**					**				X
1988Q4	**					*				X
1989Q1										

1-Sided Wald Test for Unit Root

Vintage /	Constant					Constant and Trend				
Forec. Hor.	1	2	4	8	16	1	2	4	8	16
1985Q1	**	*		X	X	X	X	X	X	X
1985Q2		*			X	X	X	X	X	X
1985Q3					X	X	X	X	X	X
1985Q4					X	X	X	X	X	X
1986Q1					X	X	X	X	X	X
1986Q2					X		X	X	X	X
1986Q3					X			X	X	X
1986Q4									X	X
1987Q1			*						X	X
1987Q2	*								X	X
1987Q3									X	X
1987Q4										X
1988Q1										X
1988Q2										X
1988Q4	**					**				X
1989Q1	*									

t1 test for unit root

Vintage /	Constant					Constant and Trend				
Forec. Hor.	1	2	4	8	16	1	2	4	8	16
1985Q1	**	**	**	X	X	X	X	X	X	X
1985Q2	**	**			X	X	X	X	X	X
1985Q3		**	*		X	X	X	X	X	X
1985Q4	*	**	*		X	X	X	X	X	X
1986Q1		**	*		X	X	X	X	X	X
1986Q2		**	*	*	X	**	X	X	X	X
1986Q3		*	*		X		*	X	X	X
1986Q4		*	*	*			**		X	X
1987Q1		*	**				**		X	X
1987Q2		*	**				**		X	X
1987Q3		*	**				**		X	X
1987Q4			*				*	*		X
1988Q1							*			X
1988Q2							*			X
1988Q4	**					**				X
1989Q1										

t2 test for Unit Root

Vintage /	Constant					Constant and Trend				
Forec. Hor.	1	2	4	8	16	1	2	4	8	16
1985Q1				X	X	X	X	X	X	X
1985Q2					X	X	X	X	X	X
1985Q3					X	X	X	X	X	X
1985Q4					X	X	X	X	X	X
1986Q1					X	X	X	X	X	X
1986Q2					X		X	X	X	X
1986Q3					X			X	X	X
1986Q4									X	X
1987Q1									X	X
1987Q2	**					*			X	X
1987Q3									X	X
1987Q4										X
1988Q1										X
1988Q2										X
1988Q4										X
1989Q1	**					*				

** denotes 5% and * denotes 10 % confidence level , X denotes a vintage that is not used due to data limitations

Table4 (Continued). TAR Unit Root Test: Vintages that reject the null hypothesis of unit root

PY Model

Vintage /	Wald test for Linearity										1-Sided Wald Test for Unit Root										t1 test for unit root										t2 test for Unit Root									
	Constant					Constant and Trend					Constant					Constant and Trend					Constant					Constant and Trend					Constant					Constant and Trend				
Forec. Hor.	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16
1985Q1					X	X	X	X	X	X					X	X	X	X	X	X	**	**	*		X	X	X	X	X	X					X	X	X	X	X	X
1985Q2					X	X	X	X	X	X					X	X	X	X	X	X	*	*			X	X	X	X	X	X					X	X	X	X	X	X
1985Q3					X	X	X	X	X	X					X	X	X	X	X	X		*			X	X	X	X	X	X					X	X	X	X	X	X
1985Q4					X	X	X	X	X	X					X	X	X	X	X	X		*			X	X	X	X	X	X					X	X	X	X	X	X
1986Q1					X	X	X	X	X	X					X	X	X	X	X	X			*		X	X	X	X	X	X					X	X	X	X	X	X
1986Q2					X	*	*	X	X	X					X			X	X	X			*		X	**	**	X	X	X					X			X	X	X
1986Q3					X	*	*		X	X					X				X	X			*		X	**	**	*	X	X					X				X	X
1986Q4						*	*		X	X									X	X	**		*			**	**	*	X	X									X	X
1987Q1									X	X									X	X	**					**	**	*	X	X									X	X
1987Q2									X	X									X	X	*					**	*	*	X	X									X	X
1987Q3									X	X									X	X	**					**	*	*	X	X									X	X
1987Q4									X	X									X	X						**	*	*	X	X									X	X
1988Q1										X										X						*	*			X										X
1988Q2										X										X						*	*			X										X
1988Q4										X										X						*	*			X										X
1989Q1																																								

P Model

Vintage /	Wald test for Linearity										1-Sided Wald Test for Unit Root										t1 test for unit root										t2 test for Unit Root									
	Constant					Constant and Trend					Constant					Constant and Trend					Constant					Constant and Trend					Constant					Constant and Trend				
Forec. Hor.	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16
1985Q1					X	X	X	X	X	X					X	X	X	X	X	X					X	X	X	X	X	X					X	X	X	X	X	X
1985Q2					X	X	X	X	X	X					X	X	X	X	X	X	*				X	X	X	X	X	X					X	X	X	X	X	X
1985Q3					X	X	X	X	X	X					X	X	X	X	X	X	*				X	X	X	X	X	X					X	X	X	X	X	X
1985Q4					X	X	X	X	X	X					X	X	X	X	X	X	*				X	X	X	X	X	X					X	X	X	X	X	X
1986Q1					X	X	X	X	X	X					X	X	X	X	X	X	*				X	X	X	X	X	X					X	X	X	X	X	X
1986Q2					X	X	X	X	X	X					X	X	X	X	X	X	*				X	X	X	X	X	X					X	X	X	X	X	X
1986Q3						*	*	X	X	X						*	*	X	X	X	*					**	**	X	X	X					*			X	X	X
1986Q4						*	*	X	X	X						*	*	X	X	X	*					**	**	X	X	X					*			X	X	X
1987Q1						*	*	*	X	X						*	*	*	X	X	*					**	**	*	X	X					*				X	X
1987Q2						*	*		X	X						*	*		X	X	*					**	**	*	X	X									X	X
1987Q3						*	*			X						*	*		*	X	**					**	**	*	*	X										X
1987Q4										X										X										X										X
1988Q1										X										X										X										X
1988Q2										X										X										X										X
1988Q4										X										X						*	*	*	*	X										X
1989Q1																																								

** denotes 5% and * denotes 10 % confidence level , X denotes a vintage that is not used due to data limitations

Table 5. ESTAR Unit Root Tests: Vintages that reject the null hypothesis of unit root

MY Model

	ESTAR1-t_{NL}										ESTAR2-t_{NL}									
Vintage /	Constant					Constant and Trend					Constant					Constant and Trend				
Forec. Hor.	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16
1985Q1					**					**					**					**
1985Q2					**					**					**					**
1985Q3																			**	
1985Q4																			**	
1986Q1																			*	
1986Q2																				
1986Q3																				
1986Q4																				
1987Q1																				
1987Q2																				
1987Q3																				
1987Q4																				
1988Q1																				
1988Q2																				
1988Q4				*																
1989Q1					**					**										

MPY Model

	ESTAR1-t_{NL}										ESTAR2-t_{NL}									
Vintage /	Constant					Constant and Trend					Constant					Constant and Trend				
Forec. Hor.	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16
1985Q1																				
1985Q2																				
1985Q3								*	*									**	**	
1985Q4								*									*	**	**	
1986Q1																		*	*	
1986Q2																		*		
1986Q3																				
1986Q4																				
1987Q1																				
1987Q2																				
1987Q3																				
1987Q4																				
1988Q1																				
1988Q2																				
1988Q4	*																			
1989Q1																				

PY Model

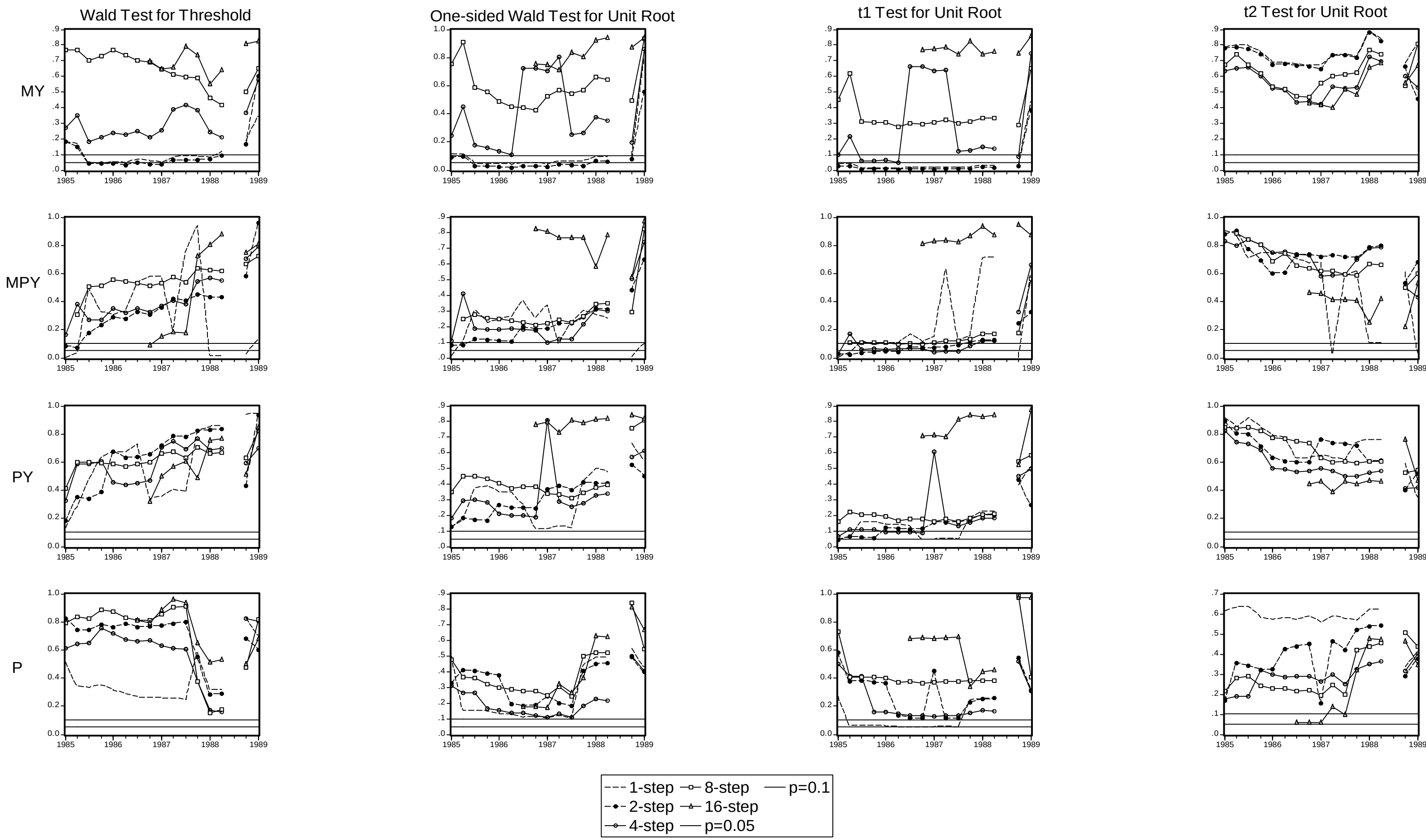
	ESTAR1-t_{NL}										ESTAR2-t_{NL}									
Vintage /	Constant					Constant and Trend					Constant					Constant and Trend				
Forec. Hor.	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16
1985Q1																				
1985Q2									*									*	*	
1985Q3									*									*	*	
1985Q4								*	*	*								**	**	*
1986Q1																		*		
1986Q2																				
1986Q3																				
1986Q4																				
1987Q1																				
1987Q2																				
1987Q3																				
1987Q4																				
1988Q1																				
1988Q2																				
1988Q4																				
1989Q1																				

P Model

	ESTAR1-t_{NL}										ESTAR2-t_{NL}									
Vintage /	Constant					Constant and Trend					Constant					Constant and Trend				
Forec. Hor.	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16	1	2	4	8	16
1985Q1			**							**										
1985Q2			**		**					**			**							*
1985Q3			**		**					**			**							*
1985Q4															**					
1986Q1					**					**										
1986Q2					**					**										
1986Q3					**					**										
1986Q4					**					**										
1987Q1					**					**										
1987Q2					**															
1987Q3				*										*						
1987Q4			*																	
1988Q1																				
1988Q2																				
1988Q4																				
1989Q1																				

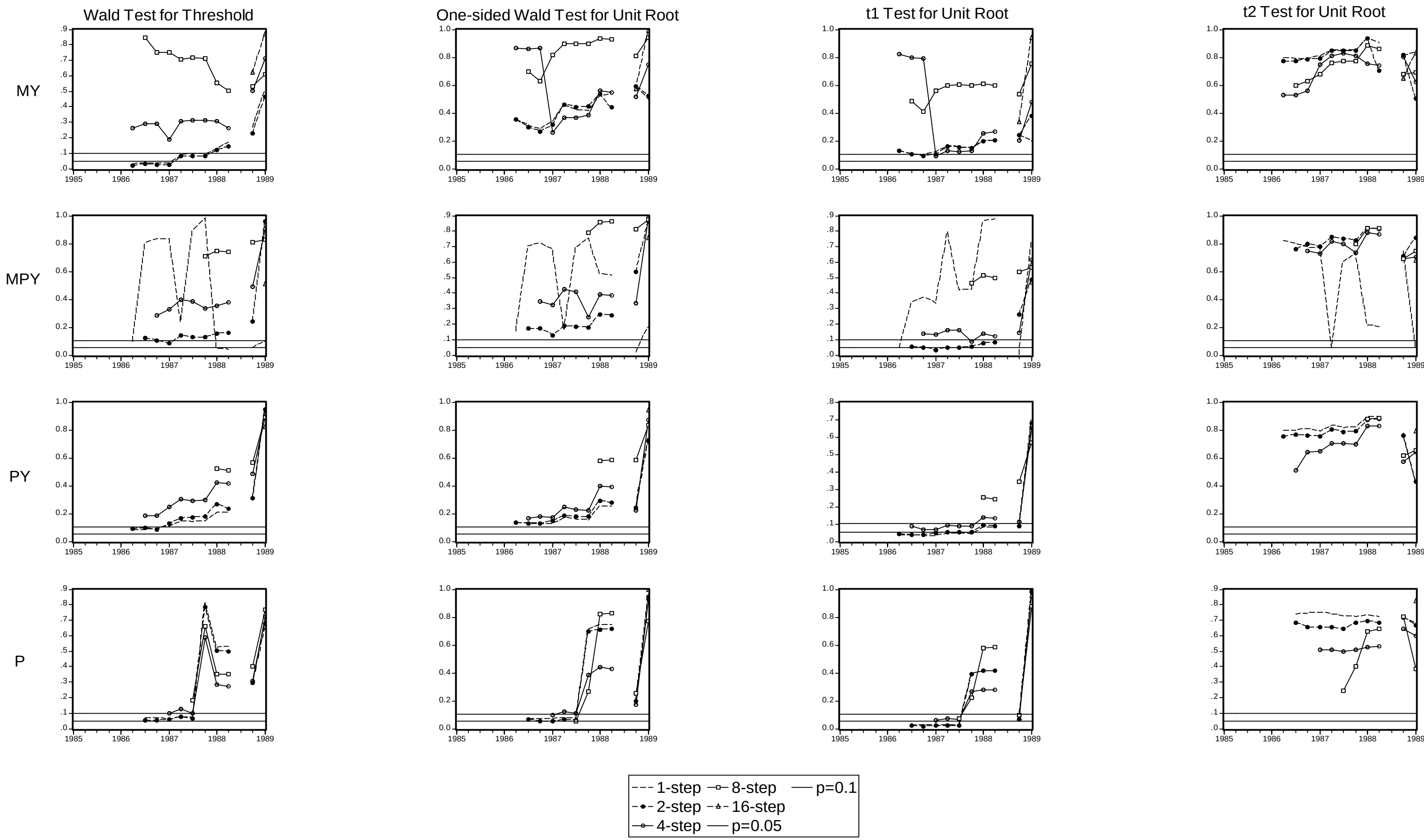
** denotes 5% and * denotes 10 % confidence level

Figure 1. Unit Root and Non-Linearity Tests: TAR Model-No Trend



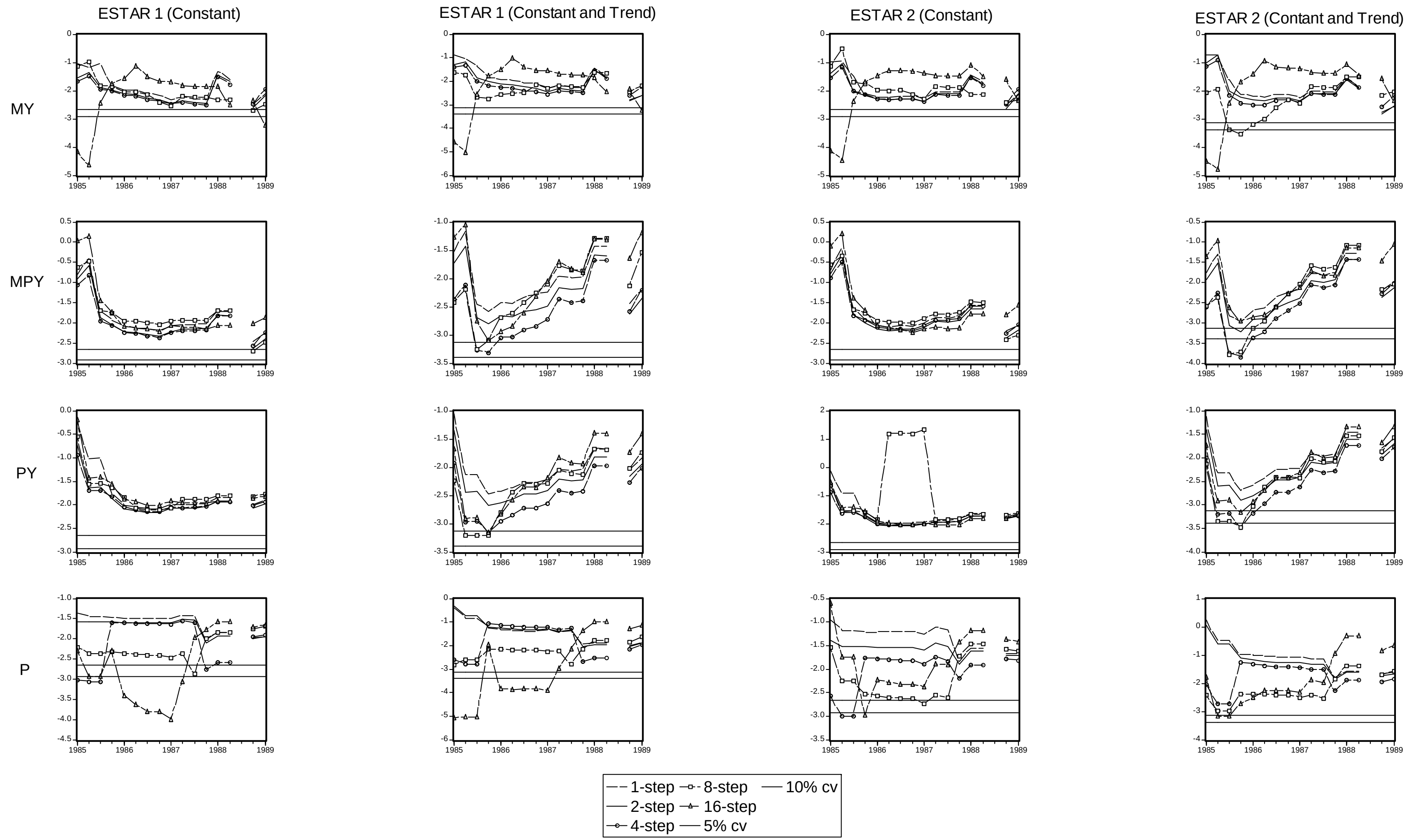
Notes: p-values of 16 different estimations from 16 different vintages

Figure 2. Unit Root and Non-Linearity Tests: TAR Model with trend



Notes: p-values of 16 different estimations from 16 different vintages

Figure 3. Unit Root and Non-Linearity Tests: ESTAR Model



Notes: t_{NL} values of 16 different estimations from 16 different vintages