THE UNIVERSITY OF TEXAS AT SAN ANTONIO, COLLEGE OF BUSINESS

Working Paper SERIES

Date February 23, 2010

WP # 0006ECO-106-2010

Nonlinearity and stationarity of inflation rates:

Evidence from the euro-zone countries

Su Zhou**
Department of Economics
University of Texas at San Antonio

UTSA COLLEGE OF BUSINESS KNOWLEDGE FOR A NEW WORLD

ONE UTSA CIRCLE
SAN ANTONIO, TEXAS 78249-0631
210 458-4317 | BUSINESS.UTSA.EDU

Nonlinearity and stationarity of inflation rates:
Evidence from the euro-zone countries*

Su Zhou**
Department of Economics
University of Texas at San Antonio

Abstract

Few studies have empirically examined the possibility of nonlinearity in inflation and tested nonlinear stationarity of the inflation rates. The present study thus intends to fill the gap. The study examines the hypothesis that, for a group of countries having exercised target-zone type stabilization policies with their inflation eventually converging to similar low levels, their inflation rates would have stationary behavior. When the sample includes periods where inflation control is an alternative objective to other objectives of policymakers and central banks respond to inflation actively only when inflation deviations from the target range become large, non-linearity may exist in inflation. The hypothesis is tested for a sample over the floating exchange rate period for 12 European countries that formed the euro zone later in the sample period. The results suggest that the majority of these countries' inflation rates can be characterized by mean reversion during the sample period. Many of them appear to be nonlinearly stationary. This finding is essential in conducting applied economic studies for these countries, when constructing models whose validity relies on whether or not inflation is stationary.

Keywords: Inflation; Unit root; Nonlinear stationarity

JEL classifications: C22; E31; F42

*Not for circulation. Not to be quoted without permission.

**Professor, Department of Economics, University of Texas at San Antonio, One UTSA Circle, San Antonio, TX 78249-0633. Tel.: +1 210 458 5398; fax: +1 210 458 5837. E-mail address: su.zhou@utsa.edu. Financial support provided by a summer research grant from the College of Business at the University of Texas at San Antonio is gratefully acknowledged.

I. Introduction

A good understanding of the dynamics of inflation is central to applied economics. It is because inflation is regarded as a key variable in many economic models, whose validity relies critically on whether or not inflation is stationary. While the accelerationist hypothesis suggests an accelerating (non-stationary) inflation rate associated with low unemployment policy, the rational expectations hypothesis proposes that stable growth of money supply implies stationary inflation (see Yellen and Akerlof, 2006). Empirical findings for the stationarity of inflation are mixed. Results of the studies vary and depend on various statistical methods adopted. Among them, studies using *linear* unit root tests for individual countries often show evidence in favor of inflation being non-stationary.[1]

Recently, a literature has evolved documenting *non-linearity* in economic variables including inflation rates. Non-linearity in inflation may reflect different speed of adjustment toward equilibrium or the level designated by policymakers. That is, the speed of adjustment increases, as the deviation of the inflation rate from the equilibrium or designated value is greater. For countries whose central banks tend to keep inflation within a target range, non-linearity in inflation may come from the response of monetary policy to inflation. As been pointed out in Orphanides and Wieland (2000), when there are more objectives than inflation stabilization, central banks may concentrate on other objectives, such as output stabilization or low unemployment, as inflation is near or within the target range. They will react to inflation primarily when inflation deviations from the target range become large. Inflation could be mean-reverting with such non-linearity but still exhibit near unit root behavior. Unit root test

[1] For examples, see Evans and Lewis (1995), Culver and Papell (1997), and Charemza et al. (2005).

procedures with a null hypothesis of nonstationarity against the alternative of linear stationarity are likely unable to reject the null and fail to detect nonlinear mean reversion in inflation.

In the existing literature, few studies have empirically examined the possibility of nonlinearity in inflation and tested nonlinear stationarity of the inflation rates. The present study thus intends to fill the gap. The study attempts to examine the hypothesis that, for a group of countries having exercised target-zone type stabilization policies with their inflation eventually converging to similar low levels, their inflation rates would have stationary behavior. When the sample includes periods where inflation control is an alternative objective to other objectives of policymakers, non-linearity may exist in their inflation. For testing this hypothesis, a sample of European countries that formed the euro zone (EZ) in 1999 appears to be particularly suitable. Most of these countries have adopted target-zone type stabilization policies since the 1970s. However, it was not until the mid-1980s did the countries realize that lower inflation rates were necessary when members of the European Monetary System (EMS) resolved to reduce inflation towards German levels (Lambertini et al., 1992, p. 334). Indeed, it is found in Clarida et al. (1998) and Doménech et al. (2002) that central banks of these countries were more permissive with inflation during the 70s than in the 80s or 90s and have tighter disinflation policies from the mid-80s onwards. In the 1990s, price stability was one of the criteria for countries to qualify for joining the euro zone. A number of previous papers (see Westbrook 1998, Fase 2002, and Duarte 2003) analyzed inflation or price level convergence in these countries by examining the stationarity of inflation differentials or testing for the cointegration relations among inflation rates, assuming that the inflation rates of these countries are nonstationary. Yet, few studies have looked into individual EZ countries for stationarity or other common properties in their inflation rates and took into account the possibility of nonlinearity in inflation.

This paper investigates the time series behavior of inflation in the floating exchange rate period for 12 European countries that formed the euro zone later in the sample period. The stationarity of inflation in this period is particularly interesting because many macro and international economic modeling and studies, including the inflation or price variable in the model, focus on the post–Bretton Woods era in which more countries have exercised target-zone type stabilization policies than in the earlier periods. The empirical tests are carried out for this period for stationarity and nonlinearity in the inflation rates of these countries. The effort is made not only on detecting the presence of nonlinearity in inflation but also on specifying which model would be appropriate in presenting the nonlinear behavior of inflation rates. A nonlinear unit root test is then applied to the series identified as having nonlinear properties. The investigation is further conducted for a sub-sample period when price stability has been the priority objective of monetary authorities of the countries in the study. It is expected that the source of non-linearity may no longer dominate the movement of inflation in the sub-sample period. Correspondingly, the inflation rates of these countries may appear to be linear stationary in the sub-period.

The rest of the paper is organized as follows. Section II describes the methodology utilized in the study. Section III provides general information regarding the sample data and presents the empirical results. The final section offers a summary of main findings and conclusions.

II. Methodological issues

We investigate non-linearity in inflation with a set of smooth transition autoregressive (STAR) models following Granger and Terasvirta (1993). Consider a STAR model of order *L*:

$$\pi_t = \alpha_{10} + \alpha_1' z_t + (\alpha_{20} + \alpha_2' z_t)\Phi(\pi_{t-d}) + v_t \tag{1}$$

where π_t is inflation rate, $z_t = (\pi_{t-1}, \ldots, \pi_{t-L})'$, $\alpha_j' = (\alpha_{j1}, \ldots, \alpha_{jL})'$, $j = 1, 2$, $d \geq 1$ is the delay parameter, v_t is an i.i.d. error with zero mean and constant variance, and $\Phi(\pi_{t-d})$ is a transition function. The exponential transition (ESTAR) function may have the following form:

$$\Phi(\pi_{t-d}) = 1 - \exp[-\theta(\pi_{t-d} - c)^2] \qquad (2)$$

where $\theta > 0$, c is a constant, and $\Phi(\pi_{t-d})$ is symmetrically U-shaped around c. The alternative logistic transition (LSTAR) function has the form below:

$$\Phi(\pi_{t-d}) = \{1 + \exp[-\theta(\pi_{t-d} - c)]\}^{-1} \qquad (3)$$

which is asymmetrically S-shaped around c. Both ESTAR and LSTAR models assume that the speed of adjustment of π_t varies with the extent of deviation from equilibrium. The main difference between the two is that ESTAR assumes a symmetric response of π_t to either positive or negative shocks, while LSTAR implies an asymmetric response of π_t to shocks of different signs.

The study is conducted first by applying the augmented Dickey–Fuller (ADF) test, a conventional unit root test, to the inflation rates in the study. The presence of nonlinearity in π_t is then tested by a three-step procedure following the suggestion of Terasvirta (1994). First, a linear autoregressive (AR) model for π_t is specified. The residuals of the AR model are saved from the chosen model and denoted as u. Second, we test for the presence of nonlinearity with different values of d, the delay parameter, through the estimation of the following model:

$$u_t = \beta_0 + \sum_{j=1}^{L} \beta_{1j}\, \pi_{t-j} + \sum_{j=1}^{L} \beta_{2j}\, \pi_{t-j}\pi_{t-d} + \sum_{j=1}^{L} \beta_{3j}\, \pi_{t-j}\pi_{t-d}^2 + \sum_{j=1}^{L} \beta_{4j}\, \pi_{t-j}\pi_{t-d}^3 + v_t \qquad (4)$$

Define $\gamma_2 = (\beta_{21}, \beta_{22}, \ldots \beta_{2L})$, $\gamma_3 = (\beta_{31}, \beta_{32}, \ldots \beta_{3L})$, and $\gamma_4 = (\beta_{41}, \beta_{42}, \ldots \beta_{4L})$. The linearity of π_t is tested on the null H_0: $\gamma_2 = \gamma_3 = \gamma_4 = 0$, with the delay parameter d corresponding to the lowest p-value in testing H_0 among a set of estimations of (4) having different values of d from 1 to 8. The last step is to choose which STAR model, LSTAR or ESTAR, would be appropriate in presenting the behavior of π_t. This is carried out through a set of F tests on testing a sequence of hypotheses with equation (4):

$$H_{01}: \gamma_4 = 0 \quad \text{versus} \quad H_{11}: \gamma_4 \neq 0 \tag{5}$$

$$H_{02}: \gamma_3 = 0 | \gamma_4 = 0 \quad \text{versus} \quad H_{12}: \gamma_3 \neq 0 | \gamma_4 = 0 \tag{6}$$

$$H_{03}: \gamma_2 = 0 | \gamma_4 = \gamma_3 = 0 \quad \text{versus} \quad H_{13}: \gamma_2 \neq 0 | \gamma_4 = \gamma_3 = 0 \tag{7}$$

Following the suggestion of Granger and Terasvirta (1993) and Terasvirta (1994), the choice of STAR model is made on the basis of the lowest p-value of these F tests. If the lowest p-value is associated with the rejection of H_{01}or H_{03}, it implies the selection of LSTAR as an appropriate model. If the rejection of H_{02} is accompanied by the lowest p-value, then the ESTAR model would be more appropriate than the LSTAR model.

Once the tests show, for π_t with nonlinearity, that most of them appear to be well described by the ESTAR model, the stationarity of these rates is further examined by the non-linear unit root tests of Kapetanios, Shin, and Snell (2003, KSS hereafter) in the ESTAR framework. For y_t being the de-meaned series of interest, the KSS tests are based on the following auxiliary regression:

$$\Delta y_t = \delta y_{t-1}^3 + \sum_{j=1}^{k} \rho_j \Delta y_{t-j} + \text{error} \tag{8}$$

which is obtained from a first-order Taylor series approximation of an ESTAR model specified in KSS (2003).[2] The null hypothesis of nonstationarity to be tested with (8) is H_0: $\delta = 0$ against the alternative of (nonlinear) stationarity H_1: $\delta < 0$. The augmentations $\sum_{j=1}^{k} \rho_j \Delta y_{t-j}$ are included to correct for serially correlated errors. KSS (2003) use the *t*-statistic for $\delta = 0$ against $\delta < 0$, referred to as the KSS statistic, but show that it does not have an asymptotic standard normal distribution. They tabulated the asymptotic critical values of the KSS statistics via stochastic simulations. In this study, the KSS tests are applied to the de-meaned data of inflation rates for which the conventional unit root tests provide no evidence of linear stationarity and the tests of Terasvirta (1994) show some evidence for the presence of nonlinearity in the series.

III. Data and empirical test results

Quarterly data used in the study are obtained from the International Financial Statistics (IFS) online for 12 euro-zone countries, namely Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Luxembourg, Portugal, and Spain. The US inflation rate is also included in the sample in order to show a comparison. It is expected that the US inflation may behave differently from those of the EZ countries and is unlikely to be stationary. The sample period runs from the first quarter of 1973 to the third quarter of 2008. Inflation rate π_t is measured as the annual percent change in the consumer price index (CPI) P_t, i.e., $\pi_t = 100 * (P_t - P_{t-4})/P_{t-4}$. Such measured rate is typically monitored by monetary policymakers.

Due to German unification in the early 1990s, the IFS has a CPI series of West Germany ending at the fourth quarter of 1991 and another CPI series for unified Germany starting from the first quarter of 1991. Therefore, German inflation is constructed by combining the part

[2] See Kapetanios et al. (2003) for more detailed derivation.

calculated from the former ending at 1991Q4 with the part computed from the latter starting from 1992Q1 [i.e., $\pi_{92Q1} = (P_{92Q1} - P_{91Q1})/P_{91Q1}$]. Such a series combined with the two parts based on two CPI series may contain a structural break. For this reason, tests for (non)stationarity in German inflation are carried out using the models with and without a structural break. Because the possible break point (denoted as T_B) coming from inflation calculation is known at 1991Q4, Perron's (1990) unit root test for a time series with a known break point is adopted. The test is performed by adding two dummy variables, DU_t and $D(TB)_t$, into the model for conventional ADF tests, where $DU_t = 0$ if $t \leq T_B$ and 1 otherwise, and $D(TB)_t = 1$ if $t = T_B + 1$ and 0 otherwise. The critical values for the test statistics are attained from Perron (1990, page 158).

Table 1 reports the results of the ADF tests with the number of augmentations k to be selected using a sequential testing procedure based on the significance of augmentation terms (i.e., insignificant terms are excluded). The maximum number of k is set to be 8 for using quarterly data.[3] The test statistics are denoted as ADF(Sig). To check the sensitivity of the test results to the number of augmentations, the ADF test is also conducted with k to be selected on the basis of the Schwarz criterion (SC) and the Ljung-Box statistic for serial correlation among the residuals.[4] The corresponding test statistics are denoted as ADF(SC).

---

[3] The sample period effectively starts from the second quarter of 1975 as the first 9 quarterly observations are used to compute the lagged inflation changes for the tests.

[4] The Schwarz criterion (SC) tends to select a model with shorter lag length. If the Ljung-Box statistic indicates serial correlation in the residuals of a model selected by SC, the model would be augmented with additional lag terms until the Ljung-Box statistic shows no significant serial correlation in the residuals.

For 4 out of 13 rates, the null of nonstationarity is rejected by both ADF(Sig) and ADF(SC) statistics at the 5% significance level and thus could be considered as linear stationary series. The test statistics for Germany, with or without including the break dummies in the model, consistently reject nonstationarity in German inflation. Among the four countries with linear stationary inflation, Belgium, Germany, and the Netherlands are core members of the EMS, and Austria, with shared historical roots, traditionally has a very close economic tie with Germany. All these four countries are in the lowest inflation group within the EZ countries over most of the sample period. The presence of nonlinearity in other nine countries' inflation rates is then tested by the procedures of Terasvirta (1994).

The results reported in the first 6 columns of Table 2 are obtained using the estimation of equation (4). The lag length L of the model is selected based on the Schwarz criterion and the Ljung-Box statistic for serial correlation. The maximum number of L is set to be 9 to be consistent with the maximum number of k equal to 8 in the ADF test in which the left-hand-side variable is the first difference of the inflation rate. The test statistics indicate that the null hypothesis of linearity is rejected for all these rates at the 5% level of significance, except for the rates of France and Greece where the null is rejected at the 15% and 10% significance levels respectively. The test is also exercised for the rates of Austria, Belgium, Germany, and the Netherlands. The results fail to reject the null of linearity at any conventional significance level with the p-values equal to 0.316, 0.308, 0.225, and 0.287, respectively, consistent with the findings of the ADF test that these four rates are linearly stationary.

For the specification of the nonlinear model, among the three F tests on the null H_{01}, H_{02}, and H_{03}, expressed in (5), (6) and (7), the lowest p-value is found on testing H_{02} for 6 out of 9 rates. The results suggest that the nonlinearity in inflation can be well presented by the ESTAR model for most of these countries. Therefore, it seems to be appropriate to apply the KSS test procedure to detect the presence of nonstationarity against nonlinear but globally stationary ESTAR process.[5]

The KSS test statistics are listed in the last two columns of Table 2. The test statistics, denoted as KSS(Sig) and KSS(SC), obtained with the lag length in the augmented model selected by the same procedures as those used in obtaining ADF(Sig) and ADF(SC), respectively. The null of nonstationarity is rejected by both KSS(Sig) and KSS(SC) in favor of the alternative of nonlinear stationarity at the 5% or 10% significance level for 6 out of 8 inflation rates of EZ countries under testing, but not for the US rate. The results indicate that many seemingly nonstationary inflation rates of the EZ countries may actually exhibit a nonlinear mean-reverting tendency during the post–Bretton Woods era.

It is further investigated that whether the nonlinearity in inflation mainly comes from the inclusion of the data of the 1970s and early 1980s, where inflation control was an alternative objective to other objectives of policymakers and central banks would respond to inflation actively only when inflation deviations from the target range became large. For a sub-sample excluding the data of the 1970s and early 1980s, would inflation behave as a linear stationary series in a period when price stability has been the priority objective of monetary authorities for most of the sample countries? To test this hypothesis, the ADF tests are applied to the inflation rates for a sub-sample period from 1983 to 2008.[6] The sub-period starts from 1983 because, in a

[5] Although the ESTAR specification in KSS (2003) may not exactly fit the ESTAR model with a large delay parameter, the rejection of the null of nonstationarity by the KSS tests and not by the ADF tests may still show well that the series under testing tends to revert to its mean nonlinearly.

[6] The effective sub-sample period starts from the second quarter of 1985 for the reason stated in footnote 3. The tests are not performed for even shorter sample because the unit root tests typically have rather low power against the null for short sample period.

number of studies for the European Monetary System (see Giavazzi and Spaventa 1990 and Artis and Taylor 1994), 1983 was considered as the beginning of a 'new EMS' period. There was a shift in the nature of the EMS to have more collective actions toward internal adjustment. During the post-1983 period, the EMS countries (most of them are currently the core members in the euro zone) became more dedicated to establishing their counter-inflationary discipline and gained credibility in stabilizing intra-EMS exchange rates through the Exchange Rate Mechanism of the EMS.

The results of the sub-sample period, reported in Table 3, indicate that the null of nonstationarity is rejected in favor of linear stationarity at the 5% significance level for almost all EZ inflation rates except those of Finland and Greece. The KSS test results reject the null for Finland but fail to do so for Greece. Neither ADF nor KSS tests reject the null of nonstationarity for the US.

IV. Conclusions

Few studies have empirically examined the possibility of nonlinearity in inflation and tested nonlinear stationarity of the inflation rates. The present study thus intends to fill the gap. The investigation is conducted for a sample over the floating exchange rate period for 12 European countries that formed the euro zone later in the sample period. It is found that, for the post–Bretton Woods period, inflation appears to be linearly stationary for 4 EZ core members who are in the lowest inflation group within these countries over most of the sample period. For the rest of 8 EZ countries, nonlinerity in their inflation is revealed and can be well presented by the ESTAR model for most of the cases. Among these 8 EZ countries, 6 of them have the inflation rate that may be characterized as being nonlinearly stationary.

It is also shown that the nonlinearity in these inflation rates may come from the inclusion of the data of the 1970s and early 1980s, where inflation control was an alternative objective to other objectives of policymakers and central banks were more permissive with inflation in this period than in the later period. For a sub-sample period starting from 1983 during which most of these counties' monetary authorities have had price stability as their priority objective, 10 out of 12 EZ inflation rates appear to be linear stationary while one is still nonlinearly stationary. In contrast, there is no evidence rejecting the null of nonstationarity for the US inflation in the period under study. Neither is evidence for stationary inflation for Greece who was the latest one joining the euro zone and had its inflation far above those of the other 11 EZ countries over the 1990s until 1999.

The study suggests that the possibility of inflation being nonlinearly stationary should be taken into consideration in macroeconomic modeling. For a sample involving the euro zone countries, their inflation should be considered as either linear or nonlinear but mean-reverting time series during the post–Bretton Woods period. This is essential in conducting applied economic analysis for these countries, when constructing models whose validity relies on whether or not inflation is stationary.

References

Artis, M. J. and Taylor, M. P. (1994) The stabilizing effect of the ERM on exchange rates and interest rates: some nonparametric tests, *International Monetary Fund Staff Papers*, 41, 123–48.

Charemza, W. W., Hristova, D. and Burridge, P. (2005) Is inflation stationary? *Applied Economics*, 37, 901-3.

Clarida, R., Galí J. and Gertler M. (1998) Monetary policy rules in practice: some international evidence, *European Economic Review*, 42, 1033–67.

Culver, S. E. and Papell, D. H. (1997) Is there a unit root in the inflation rate? Evidence from sequential break and panel data models, *Journal of Applied Econometrics*, 12, 435-44.

Doménech, R., Ledo, M. and Taguas, D. (2002) Some new results on interest rate rules in EMU and in the US, *Journal of Economics and Business*, 54, 431-46.

Duarte, M. (2003) The Euro and inflation divergence in Europe. Economic Quarterly - Federal Reserve Bank of Richmond, 89, 53-70.

Evans, M. D. and Lewis, K. K. (1995) Do expected shifts in inflation affect estimates of the long run Fisher relation? *Journal of Finance*, 50, 225–53.

Fase, M. M. G. (2002) Inflation differentials and their convergence in EMU, *De Economist*, 150, 211-17.

Giavazzi, F. and Spaventa, L. (1990) The 'new EMS'. In the European Monetary System in the 1990s, edited by De Grauwe, P. and Papademosand, L., 65–85.

Granger, C. and Terasvirta, T. (1993) Modeling nonlinear economic relationships. (Oxford University Press, New York).

Kapetanios, G., Shin, Y. and Snell A. (2003) Testing for a unit root in the nonlinear STAR framework, *Journal of Econometrics*, 112, 359-79.

Lambertini, L., Miller, M. and Sutherland, A. (1992) Inflation convergence with realignments in a two-speed Europe, *Economic Journal*, 102, 333-41.

Orphanides, A. and Wieland, V. (2000) Inflation zone targeting, *European Economic Review*, 44, 1351–87.

Perron, P. (1990) Testing for a unit root in a time series with a changing mean, *Journal of Business & Economic Statistics*, 8, 153-62.

Terasvirta, T. (1994) Specification, estimation, and evaluation of smooth transition autoregressive models, *Journal of the American Statistical Association*, 89(425), 208-18.

Westbrook, J. R. (1998) Monetary integration, inflation convergence and output shocks in the European Monetary System, *Economic Inquiry*, 36, 138-44.

Yellen, J. L. and Akerlof, G. A. (2006) Stabilization policy: a reconsideration, *Economic Inquiry*, 44, 1-22.

Table 1. ADF unit root test results (Effective sample period: 1975Q2 – 2008Q3)

Country	ADF(Sig)	ADF(SC)	Country	ADF(Sig)	ADF(SC)
Austria	-2.95[b]	-2.95[b]	Ireland	-2.96[b]	-2.73[a]
Belgium	-3.26[b]	-3.48[b]	Italy	-1.27	-1.78
Finland	-2.70[a]	-2.70[a]	Luxembourg	-2.70[a]	-2.70[a]
France	-1.73	-1.73	Netherlands	-3.05[b]	-3.11[b]
Germany	-2.94[b]	-2.94[b]	Portugal	-1.00	-1.21
Germany (with T_B)	-3.79[b]	-3.79[b]	Spain	-1.49	-1.49
Greece	-1.20	-1.20	US	-1.81	-1.81

Notes: These are the standard ADF test statistics with a constant term in the model for testing. ADF(Sig) and ADF(SC) are obtained using the augmented model with the number of augmentations being selected based on the significance testing procedure for ADF(Sig), and on the Schwarz criterion and the Ljung-Box statistic for serial correlation for ADF(SC). The 10% and 5% asymptotic critical values for the tests are -2.57 and -2.86, respectively. [a] and [b] denote rejection of the null hypothesis of nonstationarity at the 10% and 5% significance levels, respectively. The test statistics for Germany (with T_B) are obtained using Perron's (1990) unit root test for a time series with a known break point. Their 5% critical value is -3.38, reported in Perron (1990, page 158).

Table 2. Testing for nonlinearities and nonstationarity (Effective sample period: 1975Q2–2008Q3)

Country	*L*	*d*	Nonlinearity	H_{01}	H_{02}	H_{03}	KSS(Sig)	KSS(SC)
Finland	9	3	0.041	0.487	0.000*	0.442	-2.87[a]	-2.87[a]
France	9	3	0.143	0.242	0.005*	0.510	-2.81[a]	-2.81[a]
Greece	9	3	0.053	0.145	0.321	0.457	-1.99	-1.99
Ireland	5	1	0.000	0.013	0.002*	0.008	-5.65[b]	-5.02[b]
Italy	7	3	0.000	0.011	0.001*	0.015	-3.09[b]	-3.09[b]
Luxembourg	9	2	0.018	0.049	0.058	0.013*	-2.55	-2.55
Portugal	8	3	0.004	0.017	0.016*	0.024	-3.43[b]	-3.36[b]
Spain	5	1	0.000	0.000*	0.008	0.711	-2.70[a]	-2.70[a]
US	9	3	0.001	0.038	0.000*	0.336	-2.07	-2.07

Notes: The lag length *L* in the AR model is determined by the Schwarz criterion and the Ljung-Box statistic for serial correlation. The delay parameter *d* is selected corresponding to the lowest *p*-value of the linearity test using the residual series of the AR process. Numbers in the column below 'Nonlinearity' are *p*-values corresponding to the test with the null of linearity. Numbers in the columns below H_{01}, H_{02}, and H_{03} are *p*-values of the *F* tests on testing the null H_{01}: $\gamma_4 = 0$, H_{02}: $\gamma_3 = 0 | \gamma_4 = 0$, and H_{03}: $\gamma_2 = 0 | \gamma_4 = \gamma_3 = 0$, respectively. * denotes the lowest *p*-value among the three tests. A * with the *p*-value below H_{01} or H_{03} implies the appropriateness of selecting a LSTAR model, while a * with the *p*-value below H_{02} supports the choice of an ESTAR model. KSS(Sig) and KSS(SC) are the KSS test statistics obtained with the lag length in the augmented model selected by the same procedures as those used in obtaining ADF(Sig) and ADF(SC), respectively. The 10% and 5% asymptotic critical values for the KSS tests are -2.66 and -2.93, respectively, taken from Kapetanios et al. (2003, p. 364). Also see notes to Table 1.

Table 3. Unit root test results (Effective sample period: 1985Q2 – 2008Q3)

Panel A. ADF Test Statistics

Country	ADF(Sig)	ADF(SC)	Country	ADF(Sig)	ADF(SC)
Austria	-2.93[b]	-2.93[b]	Ireland	-3.35[b]	-3.16[b]
Belgium	-4.05[b]	-3.48[b]	Italy	-2.98[b]	-2.98[b]
Finland	-2.39	-2.57	Luxembourg	-3.36[b]	-3.75[b]
France	-4.10[b]	-4.10[b]	Netherlands	-3.06[b]	-3.55[b]
Germany	-2.68[a]	-2.68[a]	Portugal	-2.98[b]	-3.67[b]
Germany (with T_B)	-3.57[b]	-3.57[b]	Spain	-2.89[b]	-2.89[b]
Greece	-1.34	-1.34	US	-1.92	-1.92

Panel B. KSS Test Statistics

Country	KSS(Sig)	KSS(SC)	Country	KSS(Sig)	KSS(SC)
Finland	-3.07[b]	-3.22[b]	Greece	-2.60	-2.60
US	-1.88	-1.88			

See notes to Table 1 and Table 2.