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Mean reversion of inflation rates in 19 OECD countries: Evidence from panel Lm unit root tests with structural breaks

Chien-Chiang Lee
Department of Applied Economics, National Chung Hsing University

Chun-Ping Chang
Institute for Interdisciplinary Studies, National Sun Yat-sen University

Abstract

The paper applies the recently developed panel LM unit root tests with heterogeneous structural breaks by Im et al., [The Oxford Bulletin of Economics and Statistics, 2005] in order to re-examine the validity of mean reversion in the inflation rates of 19 OECD countries for the time period 1960-2004. Our empirical findings are favorable to the stationarity of the inflation ratesand therefore point to the absence of hyperinflation in the majority of the countries. The results indicate that most shocks to inflation rates are temporary and soon converge when we control for breaks, with the inflation rates showing mean reversion. Overall, some policy implications are obtained in this paper.

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Mean reversion of inflation rates in 19 OECD countries: Evidence from panel LM unit root tests with structural breaks

Chien-Chiang Lee*
National Chung Hsing University

Chun-Ping Chang
Shih Chien University Kaohsiung Campus

Jun-De Lee
National Chung Hsing University

Abstract

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Keywords: Panel LM unit root test; Structural breaks; Inflation; OECD
JEL classification: C33; C23; E31

* Corresponding author. Department of Applied Economics, National Chung Hsing University, Taichung, Taiwan 402. Email: ccl@nchu.edu.tw. Tel.: 886-4-22840352 x308. Fax: 886-4-22870203.
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1. INTRODUCTION

The most important responsibility of the government is maintaining full employment and stabilization of prices. If high economic growth levels imply inflation, then obviously this kind of growth will not persist. Without a doubt, the inflation rate is a key variable in the macroeconomic series for some essential reasons. For instance, the inflation phenomenon when accompanying a stable growth of money supply may have an effect on other macroeconomic variables (Cargan, 1956). From the Fisher effect viewpoint, under the condition whereby nominal interest rates contain a unit root, Mishkin (1992) conducts tests for co-integration between interest rates and inflation rates, with the results showing a delicate effect between monetary policy and inflation (Million, 2003). From the acceleration hypothesis developed by the long-run Phillips curve: If a government attempts to keep the actual unemployment rate below its natural rate, then it will have to pay a higher cost and an ever-increasing level of inflation in the long run (Lee and Wu, 2001). As Nelson and Plosser (1982) point out, the fact that a macroeconomic series often contains unit roots prompts our initial motivation for this study to try and understand the permanent or transitory characteristics of inflation behavior.

In this study we inspect the inflation trend of OECD countries in the past 50 years. As shown in Figure 1, we find these series to have gradually risen in the late 1960s and early 1970s, and then they declined in the 1980s and further declined in the early 1990s. There may be breaks in the slope of the trend function (Atkins and Chan, 2004). Most previous studies propose empirical evidence that fails to reject the unit-root null in the inflation rates of OECD countries (see Barsky, 1987; Brunner and Hess, 1993), meaning that whatever shock may have a permanent effect on inflation.[1] Hence, Camarero et al. (2000) find that through the PP (Phillips and Perron, 1988) and the KPSS (Kwiatkowski et al., 1992) unit-root tests, both present the inflation series as I (1) processes for Italy, Spain, and the UK.[2] Owing to the main advantage of panel unit root tests in that they can be used even with a small number of observations, Das and Bhattacharya (2004) and Dayanandan and Ralhan (2005) employ this new method to re-investigate whether the inflation rates mean reversion or not for India and Canada's provinces, respectively. Unfortunately, the common problem is that they do not consider the structural change of series.

Following the seminal research of Perron (1989), he found that the existence of structural breaks may produce biases in the unit root testing procedures and when they are taken into account

[1] Contrarily, Camarero et al. (2000) define a temporary shock as two cases: One is when the price variable is I (1), a one-time disturbance that leads to a temporary deviation of the inflation rate from its equilibrium value. On the other hand, if the price series is stationarity, then interestingly, though the same initial deviation of the inflation rate will occur, it will be followed in future periods by an adjustment with the opposite sign and then it converges.

[2] There is a problem with studies that rely on the conventional unit-root tests. For instance, PP (1988) and KPSS (1992) present the well-known low power of univariate unit root test in small samples.

deterministic trend models might be preferable. In response to this finding, a number of tests have been proposed which allowed for an endogenously determined single structural break (see, inter alia, Banerjee et al., 1992; Zivot and Andrews, 1992). Lumsdaine and Papell (1997) propose an ADF test which allows for two breaks. However, it has been noted by Nunes et al. (1997) that the above single-break tests are subject to size distortion and consequent spurious rejection when applied to unit root processes subject to a break. Jewell et al. (2003) show this spurious rejection to extend to the two-break setting considered by Lumsdaine and Papell (1997). In contrast, the minimum two-break LM unit root test of Jewell et al. (2003) incorporates structural change under the null hypothesis and is not subject to the above spurious rejection. The minimum LM test is therefore of interest as a rejection of the null can therefore be taken as genuine evidence of stationarity. In addition, the results of Lee and Strazicich (2003) show the minimum LM test to possess greater power than the test of Lumsdaine and Papell (1997). Furthermore, Jewell et al. (2003) also indicate that the major limitation for a conventional univariate Dickey-Fuller type panel unit root test (like the IPS and LL tests)[3] should also depend on nuisance parameters, which are an obvious hindrance to empirical researchers when allowing for structural change.[4]

To prevent the above-mentioned conditions from once more appearing, the aim and contribution of this paper is that we re-examine the validity of the mean reversion for inflation rates with annual inflation rates from 19 OECD developed countries for the time period 1960-2004 by employing the panel LM unit root test recently developed by Im et al. (2005), which has the advantage of distributing the invariance to the break point nuisance parameters and of utilizing both panel data and structural breaks when testing for a unit root. Of particular note, the method that we use is a relatively new estimation technique and has been employed quite sparingly, as it considers most breaks with the panel unit root test methods currently.[5] Based on the newest data, our results indicate that the inflation rate strongly rejects the unit-root null for selected OECD countries when we control for heterogeneous structural breaks.[6] The results report that most shocks to inflation rates are temporary and soon converge when we control for breaks. This shows mean reversion of inflation rates.

The remainder of the paper is organized as follows. Section 2 briefly describes the test of Im,

[3] Both these tests were finally published as Im et al. (2003) and Levin et al. (2002), respectively.

[4] Gadea et al. (2004) analyze the persistence of the inflation rates in UK, Italy, and Spain during the period of 1874–1998 by using the method proposed by Bai and Perron (1998) for multiple structural breaks. However, the Bai and Perron method must confirm that the series is I (0) first, and then it can test for multiple breaks.

[5] Strazicich et al. (2001) point out that it is certainly plausible to consider more than two breaks, but due to the huge computational burden in simulating critical values and finding the endogenous break points, the finite sample performance of the test has not yet been examined. Thus, we have not considered more than two breaks in each country.

[6] Corvcosier and Mojon (2005) report that this is an important limitation, because the inflation rate is usually considered as an endogenous variable, which adjusts to monetary and real developments.

et al. (2005) and Section 3 reports the empirical results. Conclusions are summarized in Section 4.

2. METHODOLOGY: THE PANEL LM UNIT ROOT TESTS WITH BREAKS

There is a large body of papers suggesting that inflation rates might follow a fractionally integrated (or I(d)) process and fractional integration may also produce mean reversion if the order of integration is smaller than 1.[7] However, Diebold and Rudebusch (1991) and Hassler and Wolters (1994) find that conventional unit root tests have extremely low power if the alternatives are of a fractional form. Dickey-Fuller type endogenous break tests, such as Zivot and Andrews (1992) (for the case of 1 break) or Lumsdaine and Papell (1997) (for two breaks), derive their distributions and critical values by not allowing for structural breaks under the null. Moreover, Nunes, Newbold and Kuan (1997) and Lee and Strazicich (2001) find that those tests suffer severe size distortions in the presence of a unit root with breaks under the null, which leads to over-rejecting the null of non-stationarity. For the above reasons, we employ Jewell et al. (2003) and Im et al. (2005)'s panel LM unit root tests whereby both the null and alternative hypotheses allow for structural breaks. We consider the following equation:

$$Y_{it} = \gamma_i' X_{it} + \varepsilon_{it}, \qquad \varepsilon_{it} = \phi_i \varepsilon_{i,t-1} + e_{it}, \tag{1}$$

for $t = 0,1,2,..T$; $i = 1,2,...,N$, where X_{it} is a vector of exogenous variables; γ_i is the corresponding parameter vector; ε_{it} is the error term of the process; and e_{it} is a zero-mean error term that allows for heterogeneous variance structure across cross-section units, but assumes no cross-correlations. Parameter ϕ_i allows for heterogeneous measures of persistence. When the data generating process follows Eq. (1), the resulting critical values of the panel unit root test are invariant to γ_i. The condition is that Y_{it} allows for two structural breaks in level (Model A) or both level and trend (Model C),[8] and D_{it} and DT^*_{it} (i=1, 2) are dummy variables that denote a mean shift and a trend shift, respectively. Therefore, let X_{it} take the form of $\left(1, t, D_{1it}, D_{2it,} DT^*_{1it}, D^*_{2it}\right)'$. From this, T_{Bi} is the location at which the break occurs for country i, and then the dummy variable takes the form $D_{it} = 1$ if $t > T_{Bi}$, and 0 otherwise, and $D_{it} = t$ if $t > T_{Bi}$, and 0 otherwise.

Another important feature of this model is that it allows for structural breaks under both the

[7] Examples are the papers of Hassler and Wolters (1994), Bos et al. (2001), Boutahar and Jouini (2005), and Hyung et al. (2006) in the context of structural breaks and Baillie (1996) for a complete revision of I (d) models.

[8] Model B allows for a shift in trend slope, but it will not be examined here as most economic time series can be adequately described by Model or C (see Perron, 1989).

null and alternative hypotheses. To see this, suppose that $\phi_i = 1$ for all "i" so that:

$$Y_{it} = \gamma_{1i} + \gamma_{2i} t + \gamma_{3i} D_{it} + \gamma_{4i} DT^*_{it} + \varepsilon_{it}, \qquad \varepsilon_{it} = \varepsilon_{it-1} + e_{it}, \tag{2}$$

where e_{it} is i.i.d. or white noise. Next, we can use the differencing transformation and solve this equation for ε_{it}, where we obtain:

$$\Delta\varepsilon_{it} = Y_{it} - Y_{i,t-1} - \gamma_{2i} - \gamma_{3i}\left(D_{it} - D_{i,t-1}\right) - \gamma_{4i}(DT^*_{it} - DT^*_{it-1}). \tag{3}$$

Sequentially, we define $B_{it} = \Delta D_{it}$, $BT_{it} = \Delta DT^*_{it}$ and let $\Delta\varepsilon_{it} \equiv \mathrm{e}_{it}$.[9] In this case, Eq. (3) can be re-written so that the model under the null becomes:

$$Y_{it} = \gamma_{2i} + \gamma_{3i} B_{it} + \gamma_{4i} BT_{it} + Y_{i,t-1} + \mathrm{e}_{it}. \tag{4}$$

In order to take the panel LM unit root test statistics, we have to compute univariate LM unit root test statistics for each country first. The procedure is as follows:

$$\Delta Y_{it} = \gamma_i' \Delta \mathrm{X}_{it} + \varphi_i \tilde{S}_{i,t-1} + u_{it}. \tag{5}$$

Here, $\tilde{S}_{i,t-1}$ is the de-trended value of $Y_{i,t-1}$ and u_{it} is the stochastic distribution term in the model. The presence of a unit root in Y_{it} for country i implies that $\varphi_i = 0$. It follows that the univariate LM test statistics can be computed using the t-test that checks $H_0 : \varphi_i = 0$ (series is non-stationary) and $H_1 : \varphi_i < 0$ (series is stationary) for each country.

As provided by Im et al. (2005),[10] the null and alternative hypotheses respectively in the panel test are given by $H_0 : \varphi_i = 0$, which means that the series of all countries contain a unit root, and when one or more countries reject the unit root, then $H_1 : \varphi_i < 0$. Synthetically, the panel LM test statistic is computed by averaging the optimal univariate LM unit root t-test statistics (LM_i^τ) estimated for each country, so that $\overline{LM}_{NT} = \frac{1}{N}\sum_{i=1}^{N} LM_i^\tau$. Standardized panel LM unit root test statistics are then constructed by letting $E(L_T)$ and $V(L_T)$ denote the expected value and variance of each country's t-test statistics, respectively, under the null hypothesis, for which the values can be taken from Table 1 of Im et al. (2005). The standardized LM panel unit root test statistics are then obtained as follows:

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[9] This is so that B_{it} (BT^*_{it}) takes on a value of 1 (t) for the time period $T_{Bi} + 1$, and 0 at all other times.

[10] There are some important features that we should note when we cite the panel LM unit root test proposed by Im et al. (2005), especially when some restrictions are relaxed. For instance, each country has unique fixed effects, varying persistence parameters, and different time trend coefficients; the heterogeneous break points are endogenously determined for each country; the number of structural breaks vary by country; the time-specific fixed effects can capture any common year structural breaks; and so on. For more detailed contents, one can refer to Im et al. (2005).

$$\Gamma_{LM} = \frac{\sqrt{N}\left[\overline{LM}_{NT} - E(L_T)\right]}{\sqrt{V(L_T)}}. \tag{6}$$

Im et al. (2005) derive the asymptotic properties of Eq. (6) and show that it has a standard normal distribution. Indeed, they show the distribution of the panel Lm unit root test statistics is unaffected by break.

3. EMPIRICAL INVESTIGATION

Annual data from 1960 to 2004 of the inflation rates that we are calculating and converting on the basis of the consumer price index (CPI) for 19 OECD countries are obtained from the International Monetary Fund's *International Financial Statistics Database*. However, in order to implement the panel LM unit root tests, we must determine the location of structural breaks in each country. The standard assay procedure is as follows: For each possible combination of breaks, the optimal lag length value of k_i is determined using the general-to-specific methods developed by Perron (1989) and Ng and Perron (1995). We determine the number of lagged augmentation terms and we start from a maximum of $k_i = 8$ lagged terms. As such, the procedure looks for significance of the last augmented term. We then use the 10% asymptotic normal value of 1.645 on the *t*-statistic of the last first-differenced lagged term. Hence, to endogenously determine the location of each break, we employ the uni-variate two-break minimum LM unit root tests as suggested in Lee and Strazicich (2003),[11] and then we use the optimal value of k_i given for each location of breaks. The final process allows for the possibility of country-specific and time-specific fixed effects in the panel test.

In order to provide a robust analysis, we first apply the LL, UB, IPS, Fisher ADF, Fisher PP, HADRI and PSP panel unit root tests without breaks to inflation rates and report the results in Table 1. Excerpt for IPS, Fisher ADF and HADRI, these results tend to indicate that there is significant evidence of mean reversion in the inflation rate. Moreover, we consider the Schmidt and Phillips (1992; SP ($\tilde{\tau}$)) uni-variate LM unit root test without structural changes in Table 2. The result shows that the unit root null can be rejected in 13 cases out 19 at the 5% significance levels. Finally, we move to extensions that allow for two breaks, since our time series covers periods during which structural change may have occurred due to the important structural reforms implemented by those countries.

The evidence showing very strong results of the panel LM unit root tests on inflation rates with

[11] They propose a grid search procedure that determines the location of breaks in each country, T_{Bi}, which is at a minimum.

time-fixed effects is shown in Tables 3 and 4 for Model A (which allows for two changes in level) and Model C (which allows for two changes in level and trend), respectively. The uni-variate LM unit root test statistics, optimal number of lagged differenced terms, and the location of the breaks appear respectively in the second, third, and last columns of each table. The last row of each table presents the panel LM test statistic. Since the value of the panel LM unit root test statistic for Model C (-45.080) is higher (absolute value) than Model A (-13.977), the use of Model C yields a testing procedure that is robust to misspecification of the form of the break. In particular, the trend dummy coefficients are all significant except for Belgium, Spain, UK and the U.S.A. Moreover, Sen (2003) also shows that the use of Model C is superior to Model A. Therefore, we focus on the analysis of Table 4 for Model C.

In Table 4, except for Austria,[12] we find that both the uni-variate and panel test results reject the null at the 5% level of significance. Clearly, the test results report that the series of inflation rates will converge in these 19 OECD countries and the result is consistent in that most shocks to inflation are temporary and soon converge when we control for breaks. Therefore, inflation rates show mean reversion. The evidence provides significant support for the inflation rate convergence hypothesis in our selected sample countries.

With respect to the first structural break in inflation rates, these are estimated to be in the 1970s for 12 countries. It is well known that a global oil and energy crisis occurred. Interestingly, there are 11 countries with two structural breaks occurring during the period 1970-1989. This result also could be attributed to the beginning of the acceleration in inflation of the 1970s that was instigated by the oil price shocks over this period.[13] Alternatively, it is possible that the breaks could be attributable to changed monetary or macroeconomic policy stances and events, such as when Corcosier and Mojon (2005) find that these changes in the mean of inflation might be due to some kind of shift in the monetary policy regime (such as Italy and France) under Taylor's Rule. Therefore, as almost all of the countries followed a disinflationary policy during the early 1980s, we expect that the price series present a deterministic trend. On the other hand, comparing to Lee and Wu (2001) and Camarero et al. (2000), we reach a conclusion for the mean reversion of inflation rates in OECD countries. It stands to reason that this strong rejection result is obtained from the increased power of the panel test in our opinion, but this paper considers the endogenous structural breaks in our econometric technique.

Based on our panel unit-root test results, the empirical findings from the previous panel's two

[12] This is because a change in the monetary policy causes the price to show a more significant fluctuation than the other countries in the 1980s and 1990s (Corcosier and Mojon, 2005).

[13] However, these phenomena are just a temporary effect.

structural breaks provide strong evidence to support that inflation rates in these 19 OECD countries are mean reverting and therefore there is an absence of hyperinflation. Some policy implications are obtained. First, the inflation rates showing mean reversion suggest that the aggregate demand policies may not be over-implemented in the sample countries since we fail to discover evidence to support the accelerated hypothesis in the long run (Lee and Wu, 2001). We believe this represents that the trade-off impact is non-existent, implying a restriction on the government's selected target, and that the independence of the policy will increase significantly. Second, if we can credit the issue from Ball and Mankiw (2002) for changes in monetary policy, then aggregate demand more generally pushes inflation and unemployment in opposite directions. Once this short-run tradeoff is admitted, there must be some level of unemployment consistent with stable inflation. Third, under the process of monetary (or interest) policy by the Central Bank, the authority does not need to pay attention to inflation, as with the Fisher effect hypothesis (Mishkin, 1992). Therefore, when the Central Bank issues currency, regulates money supply, and establishes interest rate control, it should take stabilizing prices as the first target of monetary policy; otherwise, once prices rise comprehensively, real business activities and economic decisions find it harder to operate normally. Finally, if most shocks to inflation rates are temporary, then the stabilization macroeconomic policy has long-lasting effects on the inflation rates of the OECD countries based upon our results. When the inflation rate temporarily deviates from the mean value, then at this time the administrative policy of a government should be to not adopt an excessive interfering target. This result implies that models which ignore breaks in the mean of inflation cannot avoid the wasted costs of interference, which can also increase fluctuations in other macroeconomic variables.

4. CONCLUSIONS

The issue of whether or not the inflation rate is stationary has critical implications for researchers and policy makers. This paper applies a relatively new estimation technique, which as of yet has been sparsely employed - the panel LM unit root tests with heterogeneous structural breaks by Im et al. (2005) - to re-examine the validity of the mean reversion of the inflation rates for 19 OECD countries during the period 1960–2004. Our empirical findings are favorable to the stationarity of inflation rates, and therefore show an absence of hyperinflation in the majority of the countries. These results show that most shocks to inflation rates are temporary and soon converge when we control for breaks. Hence, the inflation rates show mean reversion. Most structural breaks occurred around the period of the oil price shocks and in the 1970s and 1980s.

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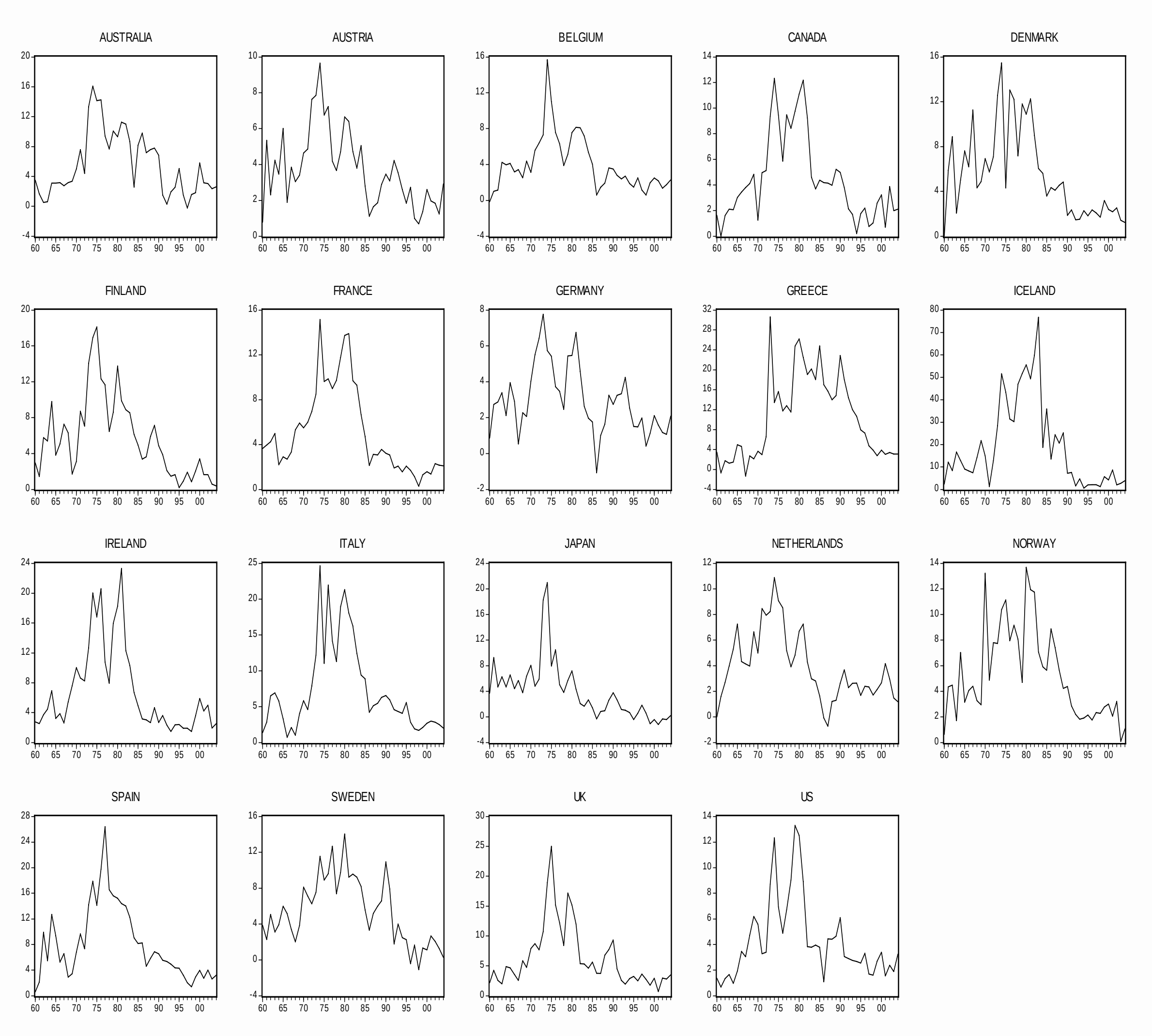

Figure 1. Plots of the inflation rate paths for 19 OECD countries, 1960-2004

Table 1. Panel unit root tests without break on the inflation rate

Method	τ
LL	-3.201**
UB	-3.241**
IPS	-0.726
Fisher ADF	42.942
Fisher PP	65.040**
HADRI	11.245**
PSP	-14.231**

Notes: LL, UB, IPS, HADRI, and PSP indicate Levin, Lin, and Chu (2002), Im et al. (2003), Breitung (2000), Hadri (2000), and Im et al. (2005) representing the panel unit root tests, respectively. Fisher-ADF and Fisher-PP denote the Maddala and Wu (1999) Fisher-ADF and Fisher-PP panel unit root tests, respectively. The LL, UB, IPS, Fisher-ADF, Fisher-PP, and PSP examine the null hypothesis of non-stationary while HADRI tests the stationary null hypothesis. The subscript τ indicates the models with both a drift as well as a deterministic trend, respectively. ** indicates significance at the 5% level. Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Table 2. Individual LM unit root test without break on the inflation rate

Country	SP ($\tilde{\tau}$) Univariate LM unit root test statistic	Optimal lag length
Australia	-6.554**	0
Austria	-2.488	1
Belgium	-5.367**	0
Canada	-1.880	2
Denmark	-4.723**	0
Finland	-4.018**	0
France	-2.001	8
Germany	-1.661	2
Greece	-2.530	1
Iceland	-4.346**	0
Ireland	-4.202**	0
Italy	-4.202**	0
Japan	-3.957**	0
Netherlands	-5.132**	0
Norway	-4.858**	0
Spain	-5.344**	0
Sweden	-5.390**	0
UK	-4.763**	0
U.S.A.	-1.463	5

Notes: SP ($\tilde{\tau}$) is individual unit-root tests without break provided by Schmidt and Phillips (1992). The 5% critical value for the LM unit root test without break is -3.11. ** denotes significance at the 5% level.

Table 3. Panel LM unit root test with two breaks on the inflation rate (Model A)

Country	Uni-variate LM unit root test statistic	Optimal lag length	Break locations
Australia	-3.762	4	1974, 1980
Austria	-3.133	8	1978, 1988
Belgium	-3.798	5	1982, 1995
Canada	-3.847**	7	1983, 1993
Denmark	-2.169	1	1973, 1975
Finland	-3.187	5	1981, 1987
France	-4.048**	8	1986, 1988
Germany	-3.361	4	1970, 1987
Greece	-4.932**	1	1976, 1979
Iceland	-4.218**	1	1980, 1991
Ireland	-3.364	6	1970, 1990
Italy	-4.384**	1	1979, 1982
Japan	-2.928	2	1976, 1984
Netherlands	-3.254	3	1977, 1985
Norway	-3.433	4	1982, 1986
Spain	-5.504**	2	1973, 1990
Sweden	-3.769	1	1981, 1987
UK	-5.146**	3	1973, 1989
U.S.A.	-4.807**	4	1984, 1989
Panel LM statistic	**-13.977** **		

Note: The 5% critical value for the LM unit root test with two breaks is -3.842. The 5% critical value for the panel LM unit root test with two breaks is -1.645. ** denotes significance at the 5% level.

Table 4. Panel LM unit root test with two breaks on the inflation rate (Model C)

Country	Univariate LM unit root test statistic	Optimal lag length	Break locations	Trend dummy coefficients	
Australia	-5.697**	8	1984, 1992	10.84**	-5.72**
Austria	-5.105	5	1983, 1993	-2.61**	-2.068**
Belgium	-7.431**	8	1972, 1985	1.07	-3.39**
Canada	-7.718**	5	1973, 1981	4.41**	-4.52**
Denmark	-13.009**	7	1973, 1981	5.54**	-5.23**
Finland	-9.110**	1	1974, 1978	4.48**	-7.04**
France	-7.794**	4	1972, 1981	4.56**	-5.12**
Germany	-8.350**	8	1975, 1986	-5.02**	-2.40**
Greece	-8.260**	6	1977, 1981	16.40**	-24.25**
Iceland	-13.490**	4	1978, 1985	-32.20**	34.85**
Ireland	-11.557**	8	1979, 1989	5.27**	-7.65**
Italy	-8.132**	1	1980, 1984	14.48**	-13.13**
Japan	-8.680**	2	1981, 1985	8.68**	-18.26**
Netherlands	-9.577**	1	1982, 1988	-3.56**	3.01**
Norway	-6.542**	8	1980, 1985	3.62**	-9.07**
Spain	-8.089**	2	1984, 1988	1.43	0.46
Sweden	-6.365**	8	1975, 1987	6.33**	-3.47**
UK	-6.464**	4	1973, 1989	1.89	-1.48
U.S.A.	-8.388**	4	1976, 1993	-1.29	1.84**
Panel LM statistic	**-45.080****				

Note: The 5% critical value for the LM unit root test with two breaks is -5.286. The 5% critical value for the panel LM unit root test with two breaks is -1.645. ** denotes significance at the 5% level.