Another Look at the Stationarity of Inflation rates in OECD countries: Application of Structural break-GARCH-based unit root tests

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Abstract

This paper re-investigates unit root hypotheses in inflation rates for 21 OECD countries using the newly proposed GARCH-based unit root tests with structural break and trend specifications. The results showed that classical tests over-accept unit roots in inflation rates, whereas these tests are not robust to heteroscedasticity. As observed from the pre-tests, those tests with structural break reject more null hypotheses of unit roots of most inflation series. By applying variants of GARCH-based unit root tests which include those with structural breaks and time trend regression specifications, we found that unit root tests without time trend gave most rejections of the conventional unit root. Thus, care should be taken while applying variants of the new unit root tests on weak trending time series as indicated in this work.

Keywords: Heteroscedasticity; Inflation rate; Structural breaks; Unit root; OECD countries
JEL Classification: C22

1. Introduction

Time series estimation of economic and financial data has undergone a shift in focus in the last four decades. The fluctuations in the time series data have been subjected to fundamental changes as a result of structural breaks and heteroscedasticity, in the form of nonlinearity. Thus, the method of estimation of such data via standard regression modelling with Ordinary Least Square (OLS) method is no longer valid. As emphasized in Dickey and Fuller (1979) and Box, Jenkins and Reinsel (2008), stationarity of the time series data must be ensured before further sensible estimation. Thus, incorporating non-stationary series while estimating OLS-based model results in misleading inferences. Instead, the estimation should be based on cointegration approach which relies on the existence of unit roots in the time series.

Various unit root tests are documented to give pre-test on the series before further model estimation. The first test is the Dickey-Fuller (DF) unit root test of Fuller (1976) and Dickey and Fuller (1979) which assumed serial un-correlation of the first differences of the time series, whereas first differences of most time series are serially correlated. The augmented component was added to the test regression model to control for the serial correlation. Augmented Dickey Fuller (ADF) (see Dickey and Fuller, 1981) and Phillips-Perron (PP) (Phillips and Perron, 1988) unit root tests were proposed simultaneously to control for serial correlation in the testing frameworks. Other unit root tests of similar testing procedures are the GLS-detrended Dickey-Fuller (Elliot, Rothenberg, and Stock, 1996), Kwiatkowski, Phillips, Schmidt, and Shin (KPSS, 1992), Schmidt and Phillips (S-P, 1992) Elliott, Rothenberg and Stock Point Optimal (ERS, 1996) and Ng and Perron (NP, 2001) unit root tests.[1] All these tests are limited in the sense that they lack power in the presence of structural breaks which is often the case in economic and financial series.

These series, at times, are stationary around a deterministic time trend which has undergone a permanent structural shift. Perron (1989) therefore observed that failure of the unit root tests to account for existing structural breaks could lead to serious bias and lead to false acceptance of unit root hypothesis in the usual ADF testing framework. Thus, an exogenous structural break dummy is allowed in the ADF test regression to control for the effect of the break as detailed in Perron (1989) unit root test. Similarly, Zivot and Andrews (Z-A, 1992), Lumsdaine and Papell (LP, 1997), Lee and Strazicich (LS, 2004), Perron (2006) proposed other versions of the structural break unit root test which allowed for one or more structural breaks to be determined along with the unit root decision. The Zivot-Andrews (Z-A) unit root test allows for only one endogenous structural break to be determined from the data. Both LP and LS unit root tests were developed by extending the endogenous structural break of Z-A (1992)

[1] Ng-Perron (2001) unit root test is a modification of Philips-Perron testing procedure.

test to allow for two endogenous structural breaks, whereas these two unit root tests are still gaining their popularities among other structural break unit root tests. A more popular unit root test which allows for one endogenously determined structural break at trend and intercept levels is the Perron (2006) unit root test, developed by extending the work of Ng-Perron (2001) unit root. The test considers both innovational and additive outlier-break types.

All these unit root tests are still lacking in their inability to capture a very salient property of economic and financial series at different time frequencies. Although, the application of ADF unit root test remains regardless of the time frequency of the data, however, when the data at hand are daily, weekly or monthly frequencies, it is not appropriate to use white noise assumption for the ADF-type tests in order to avoid size distortion problem. Thus, series of misleading inferences might have been made on data such as oil price, stocks, inflation, exchange rate, bonds, among others, since these tend to exhibit heteroscedasticity of any form. This observation was first documented in Kim and Schmidt (1993) and examined by Ling, Li and McAleer (2003) and Cook (2008). These heteroscedasticity-robust unit root tests are classified as Generalized Autoregressive Conditional Heteroscedasticity (GARCH)-based unit root tests which allow for a GARCH process in the DF test regression instead of the white noise error process in the ADF-type unit root tests. Cook (2008) based the GARCH-based unit root test on the initial work of Kim and Schmidt (1993) and Haldrup (1994), whereas these tests have their shortcomings in their inability to account simultaneously for structural breaks, which is a major concern in high frequency economic and financial data. Using Cook (2008) unit root test (and others) in the presence of structural breaks could lead to wrong inference. Following the initial work of Narayan and Popp (NP, 2010) on structural break unit root test, three other new structural break-GARCH-based unit root tests are proposed: a two-exogenously determined structural break-GARCH based unit root test by Narayan and Liu (2011, NL); a two-endogenously determined structural break-trend-GARCH based unit root test by Narayan and Liu (2015), and a two-endogenously determined structural break-GARCH based unit root test by Narayan, Liu and Westerlund (2016, NLW).

Specifically in this paper, we re-investigate unit root hypothesis of inflation rates using structural break-GARCH-based unit root tests, with data from among the Organization of Economic Cooperation and Development (OECD) countries. We consider OECD list since this will allow us a poll of inflation rates of countries of world's interest, with number of variables large enough to re-investigate unit root tests. Secondly, each of the time series is long enough to provide reliable estimates. As part of the strategy, we also carry out robustness checks on the tests by varying the size of the GARCH process.

There is the need to understand and judge correctly the stationarity property of inflation of any country since inflation targeting has been one of the contents of monetary targeting policy designed by the central banks over few years (Chang, Ranjbar and Tang, 2013). For example, if inflation follows I(1) process, then shocks affecting the series will have permanent effects, thereby shifting inflation from one equilibrium level to another. Policy makers now require a very strong decision to revert inflation rates to its original level. In the alternative, if inflation is stationary I(0) process, the effects of the shocks will be temporary, and it will be easier for the policy makers to revert inflation rates to its original level.

The empirical investigation of review on unit root hypothesis considered in this paper starts from the account of Culver and Papell (1997). These authors applied the sequential trend break and panel data modelling to investigate unit root hypothesis in inflation rates of 13 OECD countries and found rejection for unit root of four inflation rates based on individual country tests, but on applying panel data modelling, unit root hypothesis were rejected in all the 13 inflation rates. As a follow up, Basher and Westerlund (2008) applied a more powerful panel unit root tests to inflation rates in OECD countries and obtained evidence for stationarity of inflation rates. Romeo-Avila and Usabiaga (2009) investigated unit root in inflation rates of 13

OECD countries taking to consideration cross-sectional dependence and mean shifts over the periods 1957 to 2005 using panel unit root test. Their results point to stationarity of inflation rates once mean shifts in the time series are considered. Gregoriou and Kontonikas (2009) applied ADF and Ng-Perron tests to five OECD countries inflation rates and found ADF accepting the null hypothesis of unit root in inflation rates in all five countries while Ng-Perron test rejected the null hypothesis of unit root in two of the countries. Narayan and Narayan (2010) tested unit root hypothesis in 17 inflation rates from OECD countries using conventional unit root tests and the KPSS univariate test without structural breaks. The results obtained indicate non-rejection of unit root hypothesis in all the 17 inflation series, while with KPSS test, rejection of hypothesis of unit root was observed in 10 of the cases. Further investigation using panel unit root test reveals strong evidence of inflation rate for panels of the countries which are earlier picked to be nonstationary. Narayan and Popp (2011) applied modified seasonal unit root test with seasonal mean shifts proposed by Popp (2007) to inflation in G7 countries and found that none of the countries possessed seasonal unit root at monthly and annual frequencies, whereas a semi-annual unit root is found in the case of Germany. Noriega, Capistran and Ramos-Francia (2013) studied inflation persistence in 45 countries between 1960 and 2008 using a test for multiple changes in persistence and obtained mixed results on I(1)/I(0) dynamics of inflation in the countries. Lee (2015) considered unit root testing on inflation rates of 20 OECD countries using panel unit root test, taking into account cross-sectional dependence and smoothing structural changes of unknown form by the Fourier function. The ADF and other classical unit root tests indicated rejection of fewer null hypothesis of unit roots of inflation series, while on applying the panel unit root tests, all the null hypotheses of unit roots for inflation series for the 20 countries were rejected. Chang, Ranjbar and Tang (2013) applied a flexible Fourier stationary test to investigate mean reversion of inflation rates in 22 OECD countries between 1961 and 2011 and obtained evidence of mean reversion in all the countries, contrary to the mixed results obtained by the classical unit root tests. Zhou (2013) applied nonlinearity-based unit root testing procedure to examine the stationarity of inflation rates of 12 European countries that form the Euro zone. The results obtained showed that classical unit root test hardly rejects the null hypothesis of unit root due to the fact that the time series are characterized with nonlinearity which needs to be considered during the testing procedure. Upon applying the nonlinearity-based unit root test, 10 of the 12 inflation rates appear to be stationary. Gil-Alana, Yaya and Solademi (2016) considered inflation rates in Group of 7 countries and investigated unit roots hypothesis based on classical tests and fractional persistence approach with structural breaks and nonlinearity. The results obtained first indicated mixed results by the ADF, PP and Kapetanios Schmidt and Shin (KSS) tests, while upon applying the fractional persistence approach, the results showed evidence of unit roots in the cases of the UK, Canada, France, Italy, Japan and the USA, and evidence of mean reversion in the case of Germany.

Due to the importance of the decision of unit root tests in econometric time series modelling, there is the need to apply a more robust unit root tests, developed for specific time series areas. As noted, financial time series often exhibits structural breaks and nonlinearity in the form of heteroskedasticity, thus this calls for new testing procedure other than the well-known ADF unit root tests. The GARCH-based and structural break-GARCH-based unit root testing frameworks are very new testing procedures. The basis for GARCH-based unit root test is found in Kim and Schmidt (1993) who considered the first GARCH-type heteroscedasticity unit root tests for time series. Following after, Haldrup (1994), Ling, Li and McAleer (2003) and Cook (2008) applied the framework in testing unit roots in heteroscedasticity-based time series, whereas, the testing procedure is lacking in its ability to investigate simultaneously structural break and unit root in the series as in Perron (2006) and NP (2010) for the case of homoscedasticity.

Narayan and Liu (NL, 2011) presented the first structural break-GARCH-based unit root test which accommodates two structural breaks in the heteroscedastic time series. This procedure lays the foundation for Narayan's structural break GARCH-based unit root frameworks and empirical applications of these tests are found in Salisu and Mbolaji (2013), Salisu and Fasanya (2013) and Mishra and Smyth (2014). NL (2015) and NLW (2016) were developed from NL (2011). NL (2015) include both intercept and time trend in the structural break-GARCH-based unit root test, while in NLW (2016), time trend is absent while only constant is included. Other applications to NL(2015) and NLW(2016) are found in Salisu and Adeleke (2016) and Salisu et al (2016).

None of the empirical works on the newly proposed unit root testing procedures have been applied on inflation rates. Recent developments suggests that conflicting decisions often emerge while testing stationarity of inflation dynamics particularly inflation rates from developed and emerging non-African economies such as the G7, BRICS and the OECD countries.

The rest of the paper is therefore structured as follows: Section 2 presents the data and pre-test analyses which include testing for trend, heteroscedasticity, structural breaks. Section 3 presents the structural break GARCH-based unit root tests considered in the paper. Section 4 presents the results of the unit root tests, while Section 5 renders the concluding remarks.

2. The Data and Pre-test

Monthly time series of 21 inflation rates applied in this paper are sourced from Main Economic Indicators of the Organization of Economic Cooperation and Development (OECD), available at https://data.oecd.org/price/inflation-cpi.htm. These countries are Austria, Belgium, Brazil, Canada, Denmark, Finland, France, Greece, Hungary, India, Ireland, Israel, Italy, Japan, Korea, Luxemburg, Netherlands, Norway, South Africa, UK and the USA. For convenience, we have used initial classification to rename these countries, for example, Austria (AUS). Data identification and coverage for each of the time series is presented in Table 1.

INSERT TABLE 1 ABOUT HERE

Plots of the inflation time series are given in Figure 1, and based on the plots, it is very difficult decide between nonstationarity and stationarity of the inflation series, even though there are fluctuations with long spikes in most of the series.

INSERT FIGURE 1 ABOUT HERE

Descriptive statistics computed from the inflation series are presented in Table 2. These analyses include mean, maximum, minimum, standard deviation, skewness, kurtosis and Jarque-Bera (JB) test for normality. The average highest inflation rate is recorded for Brazil, while many countries in the Euro zones, in Canada and in the USA indicated average inflation rates of 3 to 4%. Most of these countries with low inflation rates present negative minimum inflation of about -2% and maximum inflation rates of two-digit of less than 30% on the average. Based on the estimates of standard deviation, it is quite obvious to observe fluctuations in inflation time series of the countries considered. Estimates of skewness are positive in all the cases, with skewness values above 0.5 in 19 of the cases. Thus, the distribution of the time series are positively skewed in these 19 cases. Platykurtosis is also observed in 19 different cases, while leptokurtosis is observed in the remaining two cases (GRE and XAF). Generally, estimates of JB test conclude that the null hypothesis of normality of inflation rates should be rejected in all the cases.

Next, we report the presence of heteroscedasticity based on ARCH test, and we found rejection of null hypothesis of homoscedasticity in all the cases. Thus, it implies that conditional heteroscedasticity is present in the time series. This also further explains the need for GARCH process in the unit root testing frameworks.

Since the unit root testing frameworks considered in this work applied trend and structural break as part of the testing procedures, we estimate both 'Trend' and 'Trend1' as presented in the last two columns of Table 2. The significance of trend coefficient in 'Trend' implies the consideration of trend in the unit root testing procedure. Similarly, 'Trend1' includes the two dummy variables D1 and D2 for the two break dates T1 and T2 as determined based on Bai-Perron (BP) multiple structural breaks test results presented in Table 4. All the trend coefficients under 'Trend' are significant, while in 'Trend1' column, the trend coefficients computed for BRA, LUX and NLD are not significant.

INSERT TABLE 2 ABOUT HERE

We present in Table 3 the results of classical unit root tests for non-structural break-based and structural break-based unit root tests. Starting with the results of DF, ADF, PP, S-P and Ng-Perron unit root tests, we observe consistency in the stationarity decision of these unit root tests for AUS, BRA, IND, JPN and KOR on significance of at least two of the unit roots for each of the series. Thus, these series seem to be stationary based on these tests. In the overall, these five unit root tests were able to reject null hypothesis of unit roots at 4, 4, 6, 4 and 6 cases of each of the tests, respectively. Looking at the results of 1-structural break unit root tests by Zivot and Andrew (Z-A) and Perron 2006, we observed more rejections of unit roots in the inflation rates. The five inflation series observed to be stationary based on DF, ADF, PP, S-P and Ng-Perron are also found to be stationary based on these structural break-based unit root tests. Based on the results of 2-structural break unit root test of NP (2010) with M1 test model, we observed 8 rejections of null hypothesis of unit root of inflation series, and the decisions reached were different from those obtained by the classical unit root tests, even though there are consistencies with those results obtained based on 1-structural break unit root tests. Due to the fact that the inclusion of structural break in the unit root testing procedure increased the rejection rates of the unit roots in time series, it implies that ADF and other similar tests over-accepts unit roots in the presence of structural breaks in the time series.

INSERT TABLE 3 ABOUT HERE

Table 4 presents the results of the number of significant breaks as well as two break dates in the inflation series based on Bai-Perron multiple structural brea6k test. Two significant break dates were identified for BRA, IND, ISR, KOR and LUX while AUS and HUN present 5 significant break dates. Since two break dates are found in all the inflation rates, the use of structural break-GARCH-based unit root tests by Cook (2008), NL(2011), NL(2015) and NLW(2016) is further justified.

INSERT TABLE 4 ABOUT HERE

3. The Structural break-GARCH based Unit root test

Beginning with the general specification of the ADF-type regression model of the form,

$$\Delta X_t = \alpha_0 + \alpha_1 t + \delta X_{t-1} + \sum_{j=1}^{k} \alpha_{3,j} \Delta X_{t-j} + \varepsilon_t \qquad (1)$$

where X_t is the time series at time *t*; ΔX_t is the first difference of the series, and ΔX_{t-j} is the lagged first differences of the series under the augmentation with parameters $\alpha_{3,i}$ ($j = 1,...,k$). The parameters, α_0 and α_1 are the intercept and coefficient of time trend, respectively, while δ determines the decision of the unit root. Thus, the null hypothesis $H_0 : \delta = 0$ for unit root is tested against the alternative hypothesis $H_1 : \delta < 0$ of no unit root with the aid of the t-statistic,

$$t_\delta = \frac{\delta}{s.e.(\delta)}$$

obtained from the test regression.

Since ADF test is not robust to structural breaks, and inference made based on the test regression in (1) is not valid for unit root testing, then NP (2010) introduced a modified ADF-type tests, in two models, both allowing for two structural breaks. The first model, termed M1 allows for two structural breaks in the intercept of the time series only, while the second model which is termed M2 allows to simultaneously test two breaks in the intercept and trend of the time series. Thus, M1 test model of NP (2010) is the basis for GARCH-based unit root tests applied in this paper, and this is specified as:

$$\Delta X_t^{M1} = \alpha_0 + \alpha_1 t + \delta X_{t-1} + \phi_1 DU'_{1,t-1} + \phi_2 DU'_{2,t-1} + \theta_1 D\left(T_B{}'\right)_{1,t} + \theta_2 D\left(T_B{}'\right)_{2,t} + \sum_{j=1}^{k} \alpha_{3,j} \Delta X_{t-j} + \varepsilon_t \quad (3)$$

where $DU'_{i,t} = 1\left(t > T'_{B,i}\right)$, $DT'_{i,t} = 1\left(t > T'_{B,i}\right) \times \left(t - T_{B,i}\right)$, $t = 1,2$, with $T'_{B,i}\left(i = 1,2\right)$ as the break dates. From model M1 in (3), the parameters ϕ_i and θ_i $\left(i = 1,2\right)$ denote the magnitude of the level and trend breaks, respectively. Similarly to ADF test described in (1), the null hypothesis of a unit root is tested as $H_0 : \delta = 1$ for unit root against the alternative hypothesis $H_1 : \delta < 1$ for the test regression model.

As a result of non-normality of the residuals, which contradicts the OLS regression assumption, NL (2011) then proposed a GARCH-based unit root test by augmenting NP (2010) M1 test regression. Thus, the proposed NL(2011) test regression model is,

$$\Delta X_t = \delta X_{t-1} + \phi_1 DU'_{1,t-1} + \phi_2 DU'_{2,t-1} + \varepsilon_t \quad (5)$$

for only the level breaks $DU'_{1,t}$ and $DU'_{2,t}$ for the break dates T_1 and T_2, respectively in the time series with,

$$\varepsilon_t = \sigma_t z_t, \ \ z_t \approx N\left(0,1\right) \quad (6)$$

$$\sigma_t^2 = a + \sum_{i=1}^{p} b_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} c_j \sigma_{t-j}^2 \quad (7)$$

where $b_i\left(i = 1,...,p\right)$ and $c_j\left(j = 1,...,q\right)$ are non-negative parameter values, and a is a strictly positive constant. The residual process ε_t is obtained as products of conditional standard deviation, σ_t and standardized normal variable, z_t. Next, by including both intercept and a time trend to the test regression model of NL(2011) in (5), together with (6) and 7), the model becomes,

$$\Delta X_t = \alpha_0 + \alpha_1 t + \delta X_{t-1} + \phi_1 DU'_{1,t-1} + \phi_2 DU'_{2,t-1} + \varepsilon_t \qquad (8)$$

which is a testing procedure proposed for modelling trending series in NL(2015). Actually, the authors found that this testing procedure outperforms NL(2011) and Cook (2008) GARCH-based unit root tests. In the case of non-trending/weak trending series, Narayan, Liu and Westerlund (NLW, 2016) silenced the trend component in NL(2015) test regression. Thus, the model included only the intercept:

$$\Delta X_t = \alpha_0 + \delta X_{t-1} + \phi_1 DU'_{1,t-1} + \phi_2 DU'_{2,t-1} + \varepsilon_t \qquad (9)$$

Cook (2008) GARCH-based unit root test regression is obtained from (9) by excluding the structural break components to obtain,

$$\Delta X_t = \alpha_0 + \delta X_{t-1} + \varepsilon_t \qquad (10)$$

The scope of the work was further extended the scope of this work by carrying out robustness checks by varying the orders of the GARCH(p,q) model as (1,2), (2,1) and (2,2).

4. GARCH-based Unit root results

The results for GARCH-based unit root tests discussed above are presented in Tables 5, 6a and 6b. Table 5 presents the standard tests based on GARCH(1,1) process, while Tables 6a and 6b present the robustness tests by varying the orders of GARCH model. From Table 5, we observe unit root rejection rates for 11, 14, 11 and 10 inflation rates corresponding to Cook (2008), NL(2011), NL(2015) and NLW(2016), respectively, and we further observed similar decision on the rejection of unit roots, which include five inflation rates (AUS, BRA, IND, JPN and KOR) picked to be stationary by classical unit root tests. We further observed similar decision on unit roots of five inflation rates (AUS, BRA, IND, JPN, KOR) based on the classical tests.

Generally, in all the four GARCH-based unit root tests, null hypothesis of unit roots were rejected in the cases of BEL, BRA, DEN, IND, IRE, ISR, KOR and NOR.

INSERT TABLE 5 ABOUT HERE

Consistency and robustness of the unit root test is investigated by varying the lag lengths of the GARCH process as GARCH(1,2), GARCH(2,1) and GARCH(2,2). These results are presented in Tables 6a [Cook (2008) and NL(2011)] and Tables 6b [NL(2015) and NLW(2016)]. A critical look at the results indicates quite much consistency in the decision of the unit root tests based on NL(2011) unit root test. Recall that this testing regression does not include constant and time trend. Thus, NL(2011) test exhibits more robustness to lag lengths than any other GARCH-based unit root test since its appears to be insensitive to the lag order of the symmetric GARCH model. Based on consistency, Cook (2008) also outperformed the other remaining two GARCH-based unit root tests.

INSERT TABLE 6a ABOUT HERE

INSERT TABLE 6b ABOUT HERE

5. Concluding remarks

The unit root hypothesis of inflation rates in 21 OECD countries was investigated using structural break GARCH-based unit root tests newly proposed in the literature. These unit root tests are the NL(2011), NL(2015) and NLW(2016) for without both intercept and trend specification, with intercept and trend specification, and the specification without only trend, respectively. These tests are based on the initial propositions of Cook(2008) for GARCH-based unit root test and NP(2010) two exogenous structural break regression test. Combining the ideas of the two strategies, NL(2011) obtained the first structural break GARCH-based unit root test.

Firstly, the pre-tests results to describe the data were obtained, the level of stationarity based on classical unit root tests, the trend, heteroscedasticity and structural break tests were determined. The results pointed to the usage of the newly proposed structural break GARCH-based unit root tests as better tests than the earlier proposed tests in the presence of heteroscedasticity and structural breaks..

It was found that classical ADF unit root test and other similar tests over-accept the null hypotheses of unit roots in inflation series in the presence of structural breaks and heteroscedasticity. Though, pre-tests results indicated significant trend in the presence of structural breaks, but unit root analyses indicated that test of NL(2011) without both intercept and trend gave the best unit root decision, with highest number of rejection of the null hypothesis. Thus, care should be taken in applying the structural break GARCH-based unit root tests, particularly in a weak and significant trend case. Also, in the case of ADF unit root testing framework for no intercept, trend only, and intercept and trend, the three tests (NL2011, NLW2016 and NL2015) are recommended to be carried out simultaneously on a weak trended time series such as inflation rates in order to properly establish the nonstationarity/stationarity level of the series. This work still agrees with Narayan and Liu (2015) and Salisu and Adeleke (2015) in the cases of trended time series, noting that the series applied in the papers are strongly trended.

References

Bai, J. and Perron, P. (2003). Computation and Analysis of Multiple Structural Change Models. Journal of Applied Econometrics, 18: 1–22.

Basher, S.A. and Westerlund, J. (2008). In there really a unit root in the inflation rate? More evidence from panel data models. Applied Economics Letters, 15(3): 161-164.

Bollerslev, T. (1986). Generalized Autoregressive Conditional Heteroscedasticity. Journal of Econometrics, 31: 307-327.

Box, G.E.P., Jenkins, G.M. and Reinsel G.C. (2008). Time Series Analysis: Forecasting and Control. 4th ed. Wiley: Hoboken, New Jersey.

Chang, T., Ranjbar, O. and Tang, D.P. (2013). Revisiting the mean reversion of inflation rates for 22 OECD countries. Economic Modelling, 30: 245-252.

Cook, S. (2008). Joint maximum likelihood estimation of unit root testing equations and GARCH processes: some finite-sample issues. Mathematics and Computers in Simulation, 77: 109–116.

Culver, S.E. and Papell, D.H. (1997). Is there a unit root in the inflation rate? Evidence from sequential break and panel data model models. Journal of Applied Econometrics, 12: 435-444.

Dickey, D.A. and Fuller, W.A. 1979. Distribution of the Estimators for Autoregressive Time Series with a Unit Root. Journal of the American Statistical Association 74: 427-431.

Dickey, D.A. and Fuller, W.A. (1981). Distribution of the estimators for autoregressive time series with a unit root. Econometrica 49, 1057–1072.

Elliot, G., Rothenberg, T.J. and Stock, J.H. (1996). Efficient tests for an Autoregressive unit root. Econometrica, 64: 813-836.

Fuller, W.A. (1976). Introduction to statistical Time Series. Wiley, New York.

Gil-Alana, L.A., Yaya, O.S. and Solademi, E.A (2016). Testing unit roots, structural breaks and linearity in the inflation rates in the G7 countries with fractional dependence techniques. Applied Stochastic Models in Business and Industry, 32: 711-724.

Gregoriou, A. and Kontonikas, A. (2009). Modelling the behaviour of inflation deviations from the target. Economic Modelling, 26: 90-95.

Huang, H.-C., lin, P.-C. and Yeh, C.-C. (2010). Price level convergence across cities? Evidence from panel unit root tests. Applied Economics Letters, 18(1): 87-93.

Kim, k. and Schmidt, P. (1993). Unit root tests with conditional heteroscedasticity. Journal of Econometrics, 26: 409-432.

Kwiatkowski, D., Phillips, P.C.B., Schmidt, P. and Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of unit root. Journal of Econometrics, 54: 159-178.

Lee, J. and Strazicich, M.C. (2003). Minimum Lagrange multiplier unit root test with two structural breaks. Review of Economic Statistics, 85: 1082–1089.

Lee, Y-J. (2015). The stationarity of the inflation rate: Evidence from OECD countries. Master thesis. Institute of Economics, National Sun Yat-sen University.

Ling, S., Li, W.K. and McAleer, M. (2003). Estimation and testing for unit root process with GARCH(1,1) errors: theory and Monte evidence. Econometric Reviews, 22: 179-202.

Lumsdaine, R.L. and Papell, D.H. (1997). Multiple trend breaks and the unit-root hypothesis. Rev. Econ. Stat. 79: 212–218.

Mishra, V. and Smyth, R. (2014). Is monthly US natural gas consumption stationary? New evidence from a GARCH unit root test with structural breaks, Energy Policy, in press.

Narayan, P.K. and Narayan, S. (2010). Is there a unit root in the inflation rate? New evidence from panel data models with multiple structural breaks. Applied Economics, 42(13): 1661-1670.

Narayan, P.K. and Popp, S. (2010). A new unit root test with two structural breaks in level and slope at unknown time. Journal of Applied Statistics, 37: 1425–1438.

Narayan, P.K. and Popp, S. (2011). An application of a new seasonal unit root test to inflation. International Review of Economics and Finance, 20: 707-716.

Narayan, P.K. and Liu, R. (2011). Are shocks to commodity prices persistent? Applied Energy, 88: 409-416.

Narayan, P. K. and Liu, R. (2015). A unit root model for trending time-series energy variables. Energy Economics, 50: 391-402.

Narayan, P.K., Liu, R. and Westerlund, J. (2016). A GARCH model for testing market efficiency. Journal of International Financial Markets Institutions and Money, 41: 121-138.

Ng, S. and Perron, P. (2001). Lag length selection and the construction of unit root tests with good size and power. Econometrica, 69: 1519-1554.

Noriega, A.E., Capistran, C. and Ramos-Francia, M. (2013). On the dynamics of inflation persistence around the world. Empirical Economics, 44: 1243-1265.

Perron, P. (1989). The Great Crash, the oil price shocks and the unit root hypothesis. Econometrica, 57: 1361-1401.

Perron, P. (2006). Dealing with structural breaks. Palgrave Handbook of Econometrics, 1, 278-352.

Phillips, P.C.B. and Perron, P. (1988). Testing for a unit root in time series regression. Biometrika, 75: 335–346.

Popp, S. (2007). Modified seasonal unit root test with seasonal level shifts at unknown time. Economics Letters, 97(2): 111-117.

Salisu, A.A. and Fasanya, I.O. (2013) Modelling oil price volatility with structural breaks. Energy Policy, 52, 554-62.

Salisu, A.A. and Mobolaji, H. (2013). Modelling returns and volatility transmission between oil Price and US-Nigeria exchange rate. Energy Economics, 39, 169-76.

Salisu, A.A. and Adeleke, A.I. (2016). Further Application of Narayan and Liu (2015) unit root model for trending time series. Economic Modelling, 55, 305-314.

Salisu, A.A., Ndako, U.B., Oloko, T.F. and Akanni, L.O. (2016). Unit root modelling for trending stock market series. Borsa Istanbul Review, 16-2: 82-91.

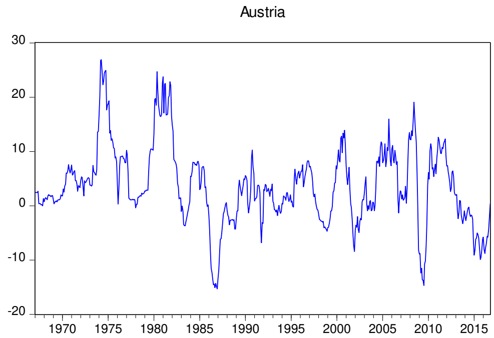
Zhou, S. (2013). Nonlinearity and stationarity of inflation rates: Evidence from the Euro-zone countries. Applied Economics, 45: 849-856.

Zivot, E. and Andrews, D.W.K. (1992). Further evidence on Great Crash, the oil price shock and the unit root hypothesis. Journal of Bus. Econ. Stat. 10: 251–270.

Table 1: Data identification and Coverage

Country	Inflation initial	Start date	End date
Austria	AUS	1967M01	2016M10
Belgium	BEL	1956M01	2016M10
Brazil	BRA	1980M12	2016M09
Canada	CAN	1950M01	2016M10
Denmark	DEN	1956M01	2016M10
Finland	FIN	1956M01	2016M10
France	FRA	1956M01	2016M10
Greece	GRE	1956M01	2016M10
Hungary	HUN	1981M01	2016M10
India	IND	1958M01	2016M09
Ireland	IRE	1956M01	2016M10
Israel	ISR	1956M01	2016M10
Italy	ITL	1956M01	2016M10
Japan	JPN	1971M01	2016M09
Korea	KOR	1952M08	2016M10
Luxemburg	LUX	1956M01	2016M10
Netherlands	NLD	1960M01	2016M10
Norway	NOR	1956M01	2016M10
South Africa	XAF	1958M01	2016M09
UK	UK	1956M01	2016M10
USA	US	1956M01	2016M10

Note: Determined by the authors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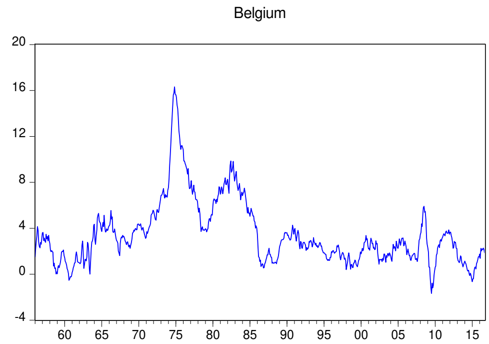
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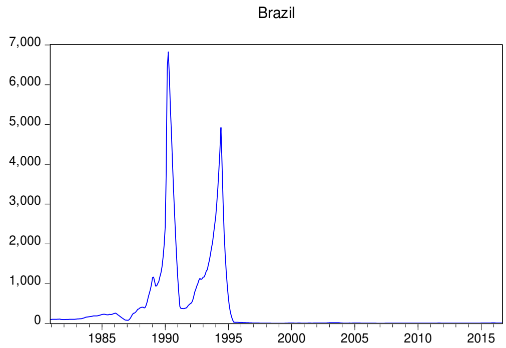
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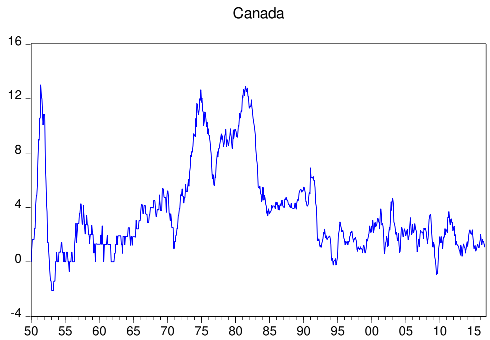
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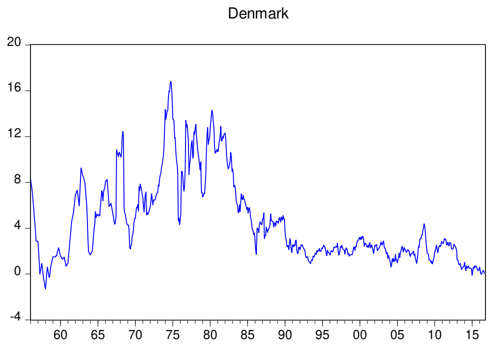
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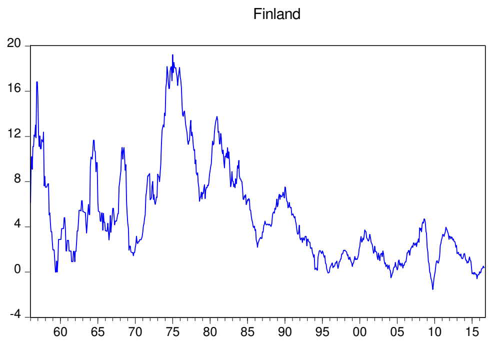
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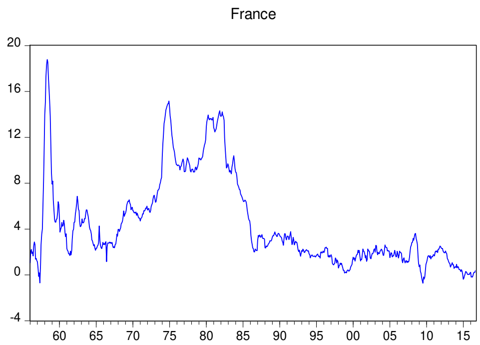
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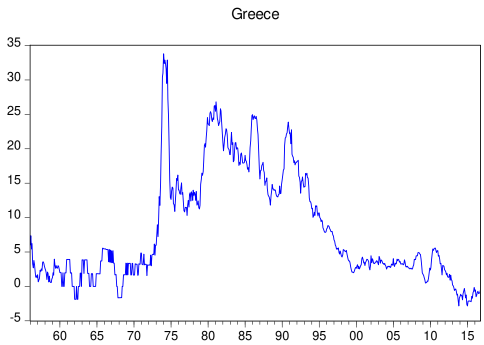
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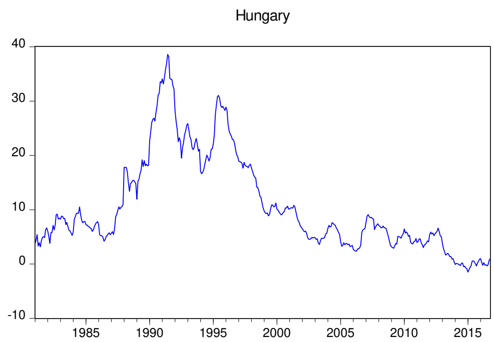
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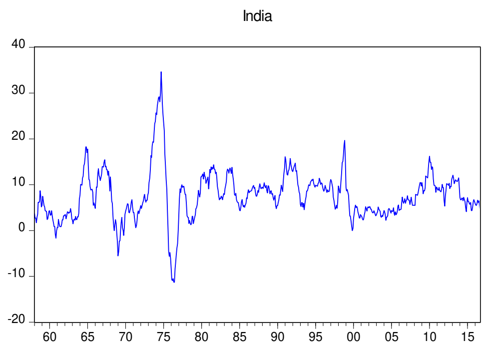
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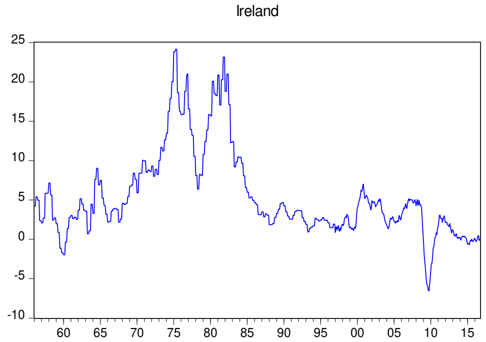
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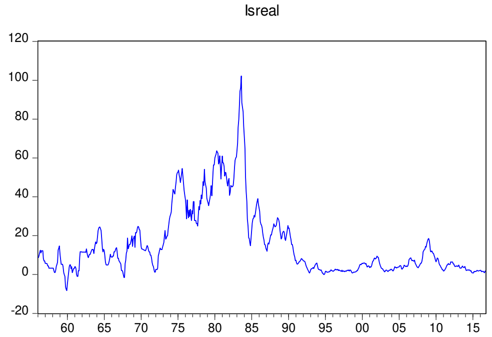
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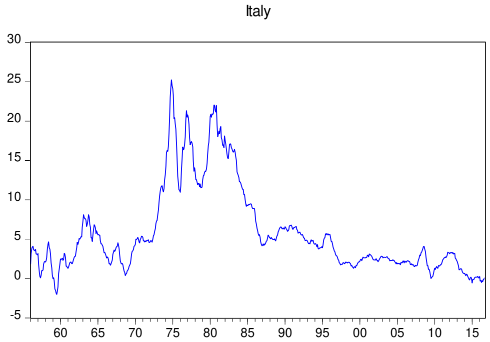
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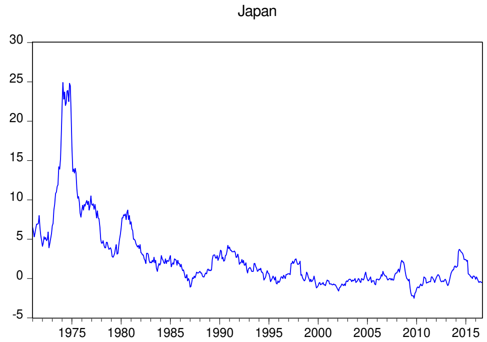
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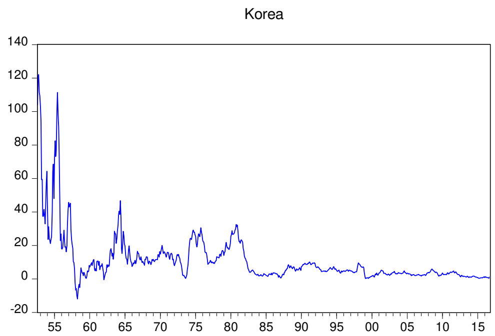
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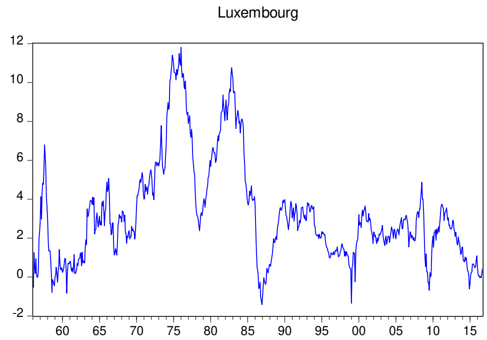
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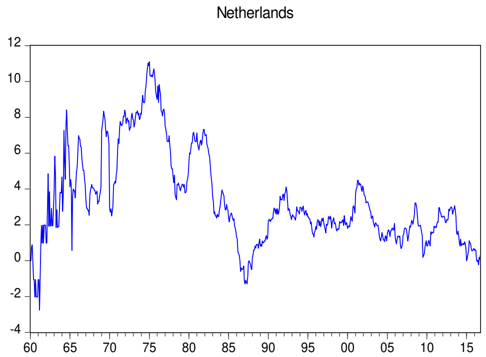
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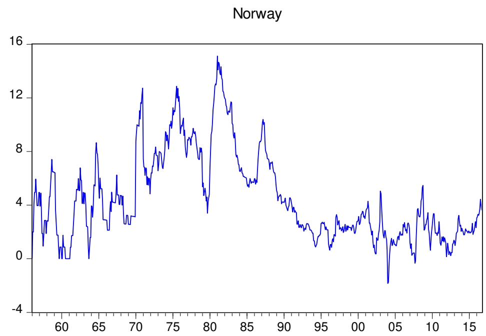
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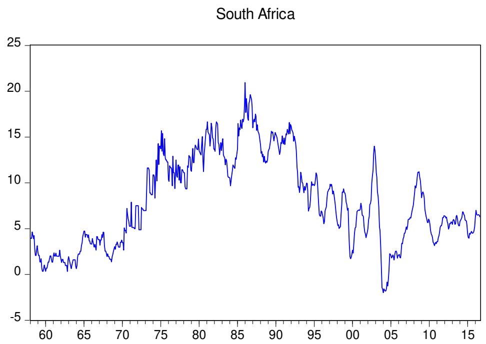
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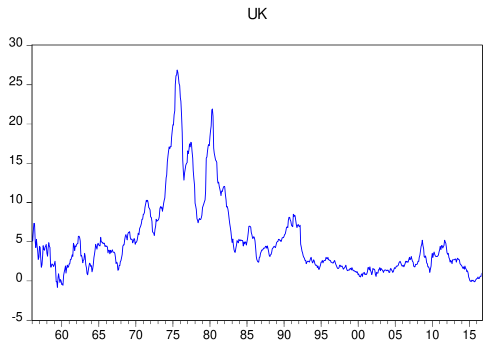
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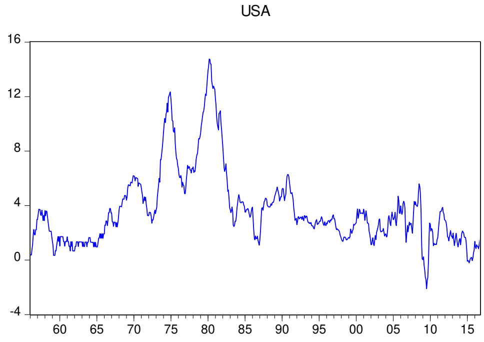

Figure 1: Plots of Inflation rates

Table 2: Descriptive Statistics Inflation rates

Country	Inflation Rate	Mean	Maximum	Minimum	S.D.	Skewness	Kurtosis	JB	ARCH(5)	Trend	Trend1
Austria	AUS	3.6415	26.9113	-15.3006	7.2044	0.3944	3.9313	37.1156***	500.159***	-0.0097***	0.0064***
Belgium	BEL	3.4548	16.3127	-1.6809	2.8138	1.6722	6.6653	748.855***	711.190***	-0.0038***	-9.9E-04***
Brazil	BRA	370.47	6821.32	1.6454	934.75	4.0091	21.244	7115.07***	380.906***	-2.1210***	0.1644
Canada	CAN	3.6338	13.0081	-2.1127	3.1844	1.1878	3.6686	203.535***	755.520***	-0.0022***	-0.0045***
Denmark	DEN	4.5340	16.8290	-1.2884	3.6909	1.0782	3.3631	145.460***	671.389***	-0.0078***	-0.0045***
Finland	FIN	5.0010	19.2405	-1.5511	4.4027	1.1082	3.6436	162.018***	682.474***	-0.0112***	-0.0118***
France	FRA	4.4451	18.7812	-0.7253	3.9606	1.2677	3.8198	215.975***	710.973***	-0.0093***	-0.0059***
Greece	GRE	8.1507	33.8028	-2.8523	8.0860	0.9006	2.7708	100.287***	679.202***	-0.0040***	-0.0154***
Hungary	HUN	10.635	38.5766	-1.4793	8.9045	1.0973	3.3552	88.5458***	413.031***	-0.0325***	-0.0343***
India	IND	7.5915	34.6422	-11.287	5.4557	0.7122	6.8442	493.700***	656.765***	-0.0020***	0.0056***
Ireland	IRE	5.4606	24.1542	-6.5637	5.5742	1.3450	4.5622	294.331***	672.813***	-0.0093***	-0.0047***
Israel	ISR	15.605	102.174	-8.2569	17.916	1.7653	6.1027	671.979***	697.151***	-0.0210***	-0.0136***
Italy	ITL	5.7936	25.2351	-2.0140	5.5538	1.4447	4.2386	300.589***	708.034***	-0.0075***	-0.0123***
Japan	JPN	2.6448	24.9000	-2.5000	4.5150	2.5982	11.124	2127.26***	517.569***	-0.0189***	-0.0041***
Korea	KOR	11.380	122.100	-11.984	16.270	3.7056	20.245	11318.6***	665.605***	-0.0394***	-0.0172***
Luxemburg	LUX	3.2441	11.8099	-1.4192	2.6814	1.1507	3.9317	187.515***	691.650***	-0.0028***	7.8E-05
Netherlands	NLD	3.3544	11.1029	-2.7601	2.6287	0.8440	3.1919	82.0137***	632.191***	-0.0063***	-0.0008
Norway	NOR	4.5201	15.1194	-1.8341	3.3072	0.9192	3.1048	103.126***	665.700***	-0.0058***	-0.0031***
South Africa	XAF	7.8949	20.9424	-1.9993	4.9328	0.2860	2.0516	36.0325***	621.500***	0.0021***	0.0035***
UK	UK	5.1252	26.8670	-0.8167	4.9468	1.9945	7.1307	1003.001***	709. 280***	-0.0075***	-0.0060***
USA	US	3.7033	14.7565	-2.0972	2.8336	1.5811	5.6511	517.917***	710.941***	-0.0028***	-0.0031***

Descriptive statistics such as mean, standard deviation (S.D.), maximum, minimum, skewness and kurtosis values are reported. Test of normality by Jarque-Bera (JB) test is presented. The ARCH test is the test of homoscedasticity of the time series against possible heteroscedasticity. 'Trend' is an OLS regression model with time trend only. 'Trend1' is an OLS regression with trend and structural break dummies D1 and D2 for T1 and T2 obtained based on Bai-Perron multiple structural break tests presented in Table 4 below.

*** indicate significance of all the tests as well as that of trend term at 5% level.

Table 3: Results of Non-GARCH-based unit root tests

Country	Inflation initial	Non-Structural break Unit root tests					1-Structural break Unit root tests		2- Structural break Unit root tests
		DF	ADF	PP	S-P	Ng-Perron	Z-A	Perron	NP 2010 M1
Austria	AUS	**-3.49[12]*****	**-3.78[12]*****	**-4.41[8]*****	**-4.18[18]*****	**-28.54[12]*****	**-5.56[4]*****	-4.82[12]	-3.92
Belgium	BEL	-2.13[16]	-2.55[16]	-2.99[12]	-2.23[18]	-10.30[16]***	-4.07[4]	-4.65[16]	-3.77
Brazil	BRA	**-4.07[2]*****	**-4.40[2]*****	**-3.95[8]*****	**-3.20[17]*****	**-33.85[2]*****	**-7.57[4]*****	**-10.46[17]*****	-3.51
Canada	CAN	-2.16[12]	-2.35[12]	-3.32[15]	-2.76[18]	-7.06[12]	-4.83[4]	-5.09[12]	-3.79
Denmark	DEN	-2.69[13]	-2.62[13]	-3.17[7]	-2.69[18]	-12.78[13]***	**-6.06[4]*****	**-5.96[13]*****	**-5.39*****
Finland	FIN	-2.54[13]	-2.61[13]	-3.23[14]	-2.80[18]	-12.56[13]	-4.71[4]	-4.33[13]	-4.16***
France	FRA	-1.56[13]	-2.96[13]	-3.27[16]	-2.35[18]	-5.32[13]	-5.97[4]***	-4.67[14]	-3.34
Greece	GRE	-1.56[14]	-1.70[14]	-2.17[14]	-2.03[18]	-5.29[14]	-5.48[4]***	-5.16[14]	-3.96
Hungary	HUN	-1.31[2]	-2.08[2]	-2.10[7]	-1.66[17]	-3.73[2]	-4.18[4]	-4.14[17]	-1.85
India	IND	**-4.32[13]*****	**-4.64[13]*****	**-4.77[15]*****	**-4.27[18]*****	**-52.79[13]*****	**-5.56[4]*****	**-5.80[19]*****	-3.13
Ireland	IRE	-1.80[12]	-2.23[12]	-2.64[12]	-2.16[18]	-7.02[12]	**-4.41[4]*****	-5.10[12]	**-4.40*****
Israel	ISR	-1.64[16]	-1.97[16]	-2.70[14]	-2.21[18]	-5.90[16]	**-6.52[4]*****	**-5.91[16]*****	-3.14
Italy	ITL	-1.06[13]	-1.70[13]	-2.23[14]	-1.80[18]	-2.61[13]	-5.10[4]***	-3.92[13]	-2.86
Japan	JPN	**-2.99[12]*****	-3.15[12]	-3.27[11]	**-3.12[18]*****	**-20.10[12]*****	-4.32[4]	**-6.83[12]*****	-2.42
Korea	KOR	-0.89[17]	**-4.36[17]*****	**-6.09[16]*****	-2.15[18]	-0.78[17]	**-8.92[4]*****	**-9.14[15]*****	**-6.06*****
Luxemburg	LUX	-1.55[12]	-2.17[12]	-3.08[11]	-2.30[18]	-4.97[12]	-4.36[4]	-5.74[18]***	-3.59
Netherlands	NLD	-1.12[13]	-3.28[13]	-3.49[4]***	-2.28[18]	-2.77[13]	-4.88[4]	-4.20[13]	**-4.90*****
Norway	NOR	-1.62[12]	-2.57[12]	-3.66[6]***	-2.67[18]	-5.14[12]	**-5.32[4]*****	-4.82[12]	**-4.77*****
S. Africa	XAF	-1.53[12]	-1.76[12]	-2.32[3]	-2.02[18]	-5.14[12]	**-5.22[4]*****	-4.26[12]	**-4.42*****
UK	UK	-2.19[14]	-2.42[14]	-2.59[15]	-2.27[18]	-10.62[14]	**-5.20[4]*****	-5.05[14]	**-4.28*****
USA	US	-1.84[13]	-2.44[13]	-2.99[11]	-2.28[18]	-7.35[13]	-4.73[4]	-6.63[16]***	-2.35
No. of rejections		4	4	6	4	6	13	8	8

Acronyms for the unit root tests: DF (Dickey-Fuller), ADF (Augmented Dickey Fuller), PP (Phillips-Perron), S-P (Schmidt-Phillips), Ng-Perron, (Z-A) Zivot-Andrews, Perron and NP(2010). Note, for PP test, the corresponding bandwidth value is in squared bracket, while for other tests, corresponding lag length for the test model information criterion is in squared bracket. Critical values for NP2010 test at 5% level of significance is 4.08, while critical levels for the other unit root tests are given in respective tables by the authors.

*** indicates significance of the tests at 5% level. The 'BLUE' denotes evidence of stationarity of inflation series in those countries by non-structural break-unit root tests, while the 'GREEN' denotes evidence of stationarity of inflation rates in those countries by structural break-unit root tests.

Table 4: Bai and Perron (2003) multiple structural breaks test

Country	Inflation initial	T_1	T_2	NSB
Austria	AUS	1974M06	1982M08	5
Belgium	BEL	1971M09	1985M08	3
Brazil	BRA	1989M08	1994M12	2
Canada	CAN	1972M09	1983M05	3
Denmark	DEN	1973M02	1983M07	3
Finland	FIN	1973M01	1984M06	3
France	FRA	1973M09	1985M07	3
Greece	GRE	1973M06	1995M02	4
Hungary	HUN	1988M01	1998M08	5
India	IND	1972M12	1999M05	2
Ireland	IRE	1973M01	1984M07	3
Israel	ISR	1973M11	1986M04	2
Italy	ITL	1973M04	1984M10	4
Japan	JPN	1977M11	1985M02	3
Korea	KOR	1962M03	1982M05	2
Luxemburg	LUX	1970M02	1984M12	2
Netherlands	NLD	1969M01	1982M12	4
Norway	NOR	1970M01	1989M01	3
South Africa	XAF	1973M03	1993M08	4
UK	UK	1973M07	1982M08	3
USA	US	1968M06	1982M09	4

Note: NSB denotes the number of significant structural breaks in each time series. The critical values of this test for the five break dates are l = 1, 2, 3, 4, 5 are 8.58, 10.13, 11.14, 11.83, 12.25, and $\hat{T}_1$ and $\hat{T}_2$ denote the two longest break sub-samples.

Table 5: Results of GARCH-based unit root tests

Country	Inflation Initial	Cook (2008)	NL (2011)	NL (2015)	NLW (2016)
Austria	AUS	-3.53***	-3.20***	-3.29	-3.38
Belgium	BEL	-3.00***	-2.89***	-4.10***	-4.12***
Brazil	BRA	7.10***	6.85***	9.11***	9.11***
Canada	CAN	-2.21	-2.48	-3.90***	-3.56
Denmark	DEN	-8.20***	-12.75***	-8.60***	-7.39***
Finland	FIN	-2.14	-2.72	-3.03	-2.65
France	FRA	-4.26***	-1.90	-7.20***	-4.92***
Greece	GRE	-2.24	-3.14***	-3.82	-2.87
Hungary	HUN	-1.98	-3.97***	-3.25	-1.76
India	IND	-3.54***	-3.64***	-4.21***	-4.25***
Ireland	IRE	-3.81***	-3.72***	-4.06***	-5.34***
Israel	ISR	-2.69	-4.29***	-4.99***	-5.14***
Italy	ITL	-3.00***	-0.93	-3.07	-2.18
Japan	JPN	-3.48***	-3.83***	-4.09***	-3.61
Korea	KOR	-3.76***	-6.05***	-5.74***	-4.95***
Luxemburg	LUX	-2.28	-3.52***	-3.65	-3.61
Netherlands	NLD	-2.11	-2.64	-3.33	-3.20
Norway	NOR	-2.97***	-3.23***	-4.17***	-4.23***
South Africa	XAF	-2.60	-3.39***	-3.82	-3.78***
UK	UK	-2.64	-2.35	-2.67	-2.74
USA	US	-2.40	-1.75	-2.98	-2.86
No. of rejections		11	14	11	10

Note: For consistency, we only made inference on the tests at 5% significant levels. Thus, critical values for Cook (2008), NL(2011), NL(2015) and NLW(2016) unit root tests are -2.86, -2.87, -3.89 and -3.66, respectively.

*** denotes statistical significance of the unit root tests.

Table 6a: Robustness tests

Cook (2008)					NL (2011)				
Country	**Inflation Initial**	**GARCH(1,2)**	**GARCH(2,1)**	**GARCH(2,2)**	**Country**	**Inflation Initial**	**GARCH(1,2)**	**GARCH(2,1)**	**GARCH(2,2)**
Austria	AUS	-3.79***	-3.90***	-4.02***	Austria	AUS	-3.41***	-3.47***	-3.57***
Belgium	BEL	-3.01***	-3.03***	-3.03***	Belgium	BEL	-3.01***	-3.02***	-3.01***
Brazil	BRA	-0.04	76.11***	1.33	Brazil	BRA	6.38***	5.02***	5.06***
Canada	CAN	-2.20	-2.49	-2.43	Canada	CAN	-2.14	-2.64	-2.56
Denmark	DEN	-2.32	-3.65***	-5.80***	Denmark	DEN	-12.28***	-8.68***	-7.32***
Finland	FIN	-2.15	-2.11	-2.17	Finland	FIN	-2.95***	-2.84	-2.98***
France	FRA	-3.04***	-2.54	-2.55	France	FRA	-1.68	-1.50	-1.02
Greece	GRE	-2.55	-2.32	-2.21	Greece	GRE	-3.07***	-2.69	-2.58
Hungary	HUN	-2.09	-2.13	-2.33	Hungary	HUN	-4.25***	-4.81***	-4.40***
India	IND	-3.57***	-3.58***	-3.57***	India	IND	-3.60***	-3.58***	-3.58***
Ireland	IRE	-3.90***	-0.52	-29.71***	Ireland	IRE	-4.10***	-3.00	-1.47
Israel	ISR	-2.57	-2.69	-2.56	Israel	ISR	-4.23***	-5.02***	-5.80***
Italy	ITL	-2.95***	-3.16***	-3.15	Italy	ITL	-0.85	-0.77	-0.73
Japan	JPN	-3.50***	-3.50***	-3.52***	Japan	JPN	-3.77***	-3.80***	-3.79***
Korea	KOR	-3.76***	-3.71***	-3.72***	Korea	KOR	-6.00***	-5.91***	-5.90***
Luxemburg	LUX	-2.06	-1.95	-1.83	Luxemburg	LUX	-3.39***	-3.13	-2.72
Netherlands	NLD	-2.07	-2.04	-1.98	Netherlands	NLD	-2.64	-2.61	-81.83***
Norway	NOR	-2.87***	-2.88***	-3.08***	Norway	NOR	-3.20***	-3.22***	-3.17***
South Africa	XAF	-2.50	-2.29	-2.22	South Africa	XAF	-3.40***	-3.54***	-3.57***
UK	UK	-2.83***	-2.71	-2.91***	UK	UK	-0.49	-0.74	-0.41
USA	US	-2.39***	-2.56	-2.51	USA	US	-1.82	-1.96	-1.95
No. of rejections		11	9	9	No. of rejections		15	11	13

Note: For consistency, we only made inference on the tests at 5% significant levels. Thus, critical values for Cook (2008), NL(2011), NL(2015) and NLW(2016) unit root tests are -2.86, -2.87, -3.89 and -3.66, respectively. Statistical significance of the test is therefore denoted by ***. Thus, decision on the stationarity of inflation series is reached based on rejection of at least three null hypotheses of the four tests, at 5% level of significance, and these rejections always included that of NL(2015) test.

Table 6b: Robustness tests (cont'd)

NL (2015)					NLW (2016)				
Country	**Inflation Initial**	**GARCH(1,2)**	**GARCH(2,1)**	**GARCH(2,2)**	**Country**	**Inflation Initial**	**GARCH(1,2)**	**GARCH(2,1)**	**GARCH(2,2)**
Austria	AUS	-3.61	-3.64	-3.77	Austria	AUS	-3.60	-3.63	-3.76***
Belgium	BEL	-4.10***	-4.12***	-4.11***	Belgium	BEL	-4.12***	-4.14***	-4.13***
Brazil	BRA	-4.59***	-1.33	15.55***	Brazil	BRA	2.30	9.48***	-2.57
Canada	CAN	-3.49	-4.12***	-4.04***	Canada	CAN	-3.12	-3.74***	-3.66***
Denmark	DEN	-8.51***	-6.49***	-5.56***	Denmark	DEN	-5.70***	-4.72***	-2.77
Finland	FIN	-3.00	-2.84	-2.98	Finland	FIN	-2.61	-2.42	-2.69
France	FRA	-5.99***	-5.84***	-5.92***	France	FRA	-4.04***	-3.53	-3.68***
Greece	GRE	-4.01***	-3.52	-3.27	Greece	GRE	-3.16	-2.77	-2.55
Hungary	HUN	-3.41	-1.20	-2.09	Hungary	HUN	-1.87	-2.12	-2.70
India	IND	-4.16***	-4.15***	-4.15***	India	IND	-4.23***	-4.22***	-4.22***
Ireland	IRE	-4.39***	-1.01	-3.12	Ireland	IRE	-3.77***	-1.55	-5.40***
Israel	ISR	-5.16***	-5.08***	-5.17***	Israel	ISR	-5.30***	-5.21***	-5.30***
Italy	ITL	-2.88	-2.87	-2.86	Italy	ITL	-2.08	-2.13	-2.11
Japan	JPN	-4.25***	-4.72***	-4.68***	Japan	JPN	-3.76***	-4.10***	-4.10***
Korea	KOR	-5.68***	-5.70***	-5.68***	Korea	KOR	-4.86***	-4.78***	-4.78***
Luxemburg	LUX	-3.45	-3.40	-3.27	Luxemburg	LUX	-3.41	-3.36	-3.15
Netherlands	NLD	-3.23	-3.04	-3.39	Netherlands	NLD	-3.10	-2.93	-4.30***
Norway	NOR	-4.15***	-4.10***	-4.67***	Norway	NOR	-4.22***	-4.16***	-4.71***
South Africa	XAF	-3.68	-3.56	-3.52	South Africa	XAF	-3.61	-3.45	-3.40
UK	UK	-2.65	-2.86	-2.70	UK	UK	-2.73	-2.93	-2.79
USA	US	-2.95	-3.14	-3.11	USA	US	-2.85	-3.05	-3.02
No. of rejections		11	9	10	No. of rejections		9	9	11

Note: For consistency, we only made inference on the tests at 5% significant levels. Thus, critical values for Cook (2008), NL(2011), NL(2015) and NLW(2016) unit root tests are -2.86, -2.87, -3.89 and -3.66, respectively. Statistical significance of the test is therefore denoted by ***. Thus, decision on the stationarity of inflation series is reached based on rejection of at least three null hypotheses of the four tests, at 5% level of significance, and these rejections always included that of NL(2015) test.