Mean Reversion of Inflation Rates: Evidence from 13 OECD countries

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Abstract

The stationarity of inflation has several important economic implications. This paper applies two recently developed panel unit root tests to re-examine the stationarity of inflation rates in 13 OECD countries. We provide strong empirical evidence to support the mean reversion of inflation rates. Our finding fails to support the accelerationist hypothesis and it also points out that the conventional cointegration approach in analyzing the Fisher effect and the convergence of inflation rates may not be appropriate.

Keywords: Inflation; Accelerationist hypothesis; Panel data unit root tests; Bootstrap.

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1. Introduction

It is a well-established empirical fact that many time series of macro data have unit roots. This was first argued systematically in the influential article of Nelson and Plosser (1982). The inflation rate is clearly one of the key variables in understanding the macroeconomy. Whether inflation is best described as a stationary or a unit root process has a number of economic implications. First, the rational expectation version of Cagan (1956) indicates that stable growth of money supply implies stationary inflation unless there exists bubbles. Second, a unit root in inflation is consistent with the accelerationist hypothesis which implies a non-stationary inflation rate.[1] Third, it is widely accepted that nominal interest rates contain a unit root. Hence, Fisher effect tests are possible if inflation and interest rate series are integrated of order one (Koustas and Serletis, 1999 and Mishkin, 1992). Fourth, if inflation rates are non-stationary, an inflation convergence within the European Monetary System (EMS) might be identified with cointegration between inflation rates in Germany and each of the other EMS countries (Artis and Nachane, 1990 and Caporale and Pittis, 1993).

The empirical evidence in related literature does not provide a consensus agreement about the stationarity of inflation. Nelson and Schwert (1977), Barsky (1987), MacDonald and Murphy (1989), Ball and Cecchetti (1990), and Brunner and Hess (1993) fail to reject the unit-root null in inflation. Therefore, any shock to inflation has a permanent effect. However, Baillie, Chung and Tieslau (1996) find that inflation rates among industrial countries are fractionally integrated so that it is mean-reverting with finite cumulative impulse response weights.

The previous mentioned literature applies a single-equation test to examine the unit-root null of inflation rates. Ever since the pioneer work of Abuaf and Jorion (1990) and Levin and Lin (1992), it is well known that the power of the unit-root test for a given sample size can be increased by exploiting cross-sectional information. Levin and Lin (1992) demonstrate that implementing a unit-root test on a pooled cross-sectional data set, rather than performing separate unit-root tests for each individual series, can provide 'dramatic improvement in statistical power.' Based on the system method of Abuaf and Jorion (1990), Culver and Papell (1997) reject the unit-root null of inflation. The major limitation of the Abuaf-Jorion test is their restriction of the same long-run multiplier across countries under the alternative hypothesis. This may be a restrictive assumption in applied works. In addition, Culver and Papell (1997) ignore the effect of contemporaneous correlation of innovations in their Monte-Carlo simulations and O'Connell (1998) points out that there are dramatic size distortions for panel unit root tests in the presence of contemporaneous correlation.

To address the limitation of the Abuaf-Jorion test, Im, Pesaran and Shin (1997, IPS) propose a new panel unit-root test based on the mean group approach. Moreover, they show that their t-bar statistic achieves a more accurate size and a higher power relative to the Levin-Lin test. To take into account the contemporaneous correlation and serial correlation in innovations, we apply a non-parametric bootstrap to simulate our critical values. However, Taylor and Sarno (1998) and Karlsson and Lothgren (2000) point out a potential pitfall in applying panel unit root tests. The pitfall is: panel unit root tests may lead to a very high probability of rejection of the joint unit-root null when there is a single stationary series in a system of an otherwise unit-root process. To avoid this pitfall, Taylor and Sarno (1998) suggest using the JLR test as a complement to panel unit root tests. The null hypothesis of the JLR test is that there is at least one non-stationary series in the panel. This null is only violated if all of the series are stationary. Therefore, the rejection of the null with the JLR test implies that all series are stationary. The purpose of this paper is to apply both the IPS test and the JLR test to re-examine the unit-root null of inflation rates. Our empirical evidence strongly supports that the inflation rates of thirteen OECD countries are mean reverting.

The remainder of the paper is organized as follows. Section 2 describes the econometric strategy. Section 3 reports our empirical results from the IPS test and the JLR test, respectively. Critical values are simulated to correct for a small sample bias. Finally, the conclusion is summarized in the last section.

2. Econometric strategy

Suppose that there is a group of N inflation rates, which have the following time-series representation:

$$\Delta\pi_{it} = \alpha_i + \phi_i \pi_{it-1} + \sum_{j=1}^{w_i} \gamma_{ij} \Delta\pi_{it-j} + \zeta_{it}, \tag{1}$$

where π_{it} denote the inflation rate in country i at time t and ζ_{it} is assumed to be uncorrelated over time. The IPS test examines the null hypothesis:[2]

$$H_0: \ \phi_1 = \phi_2 = ... = \phi_N = 0,$$

against

$$H_a: \ \phi_i < 0, \text{ for some i.}$$

Let's define the t statistic of $\hat{\phi}_i = 0$, based on T observations, in (1) as $t_{iT}(w_i)$. The IPS's t-bar statistic is defined as follows:

$$\bar{z}_{1NT} = \sqrt{N}[\bar{t}_{NT} - E(\bar{t}_{NT})] / \sqrt{Var(\bar{t}_{NT})}, \tag{2}$$

where $\bar{t}_{NT} = (1/N)\sum_{i=1}^{N} t_{iT}(w_i)$, with mean $E(\bar{t}_{NT})$ and variance $Var(\bar{t}_{NT})$. The limiting distribution of $\bar{z}_{1NT}$ is standard normal. The adjustment terms in $\bar{z}_{1NT}$, mean $E(\bar{t}_{NT})$ and variance $Var(\bar{t}_{NT})$, depend on the selection of the lag length w_i and the time span T. They are generated by a simulation through 100,000 iterations.

Note that the ζ_{it}'s in (1) are likely to be contemporaneously correlated. With the existence of contemporaneous correlation in residuals, the asymptotic distribution of the IPS's t-bar statistic, $\bar{z}_{1NT}$, is unknown. We therefore simulate the finite sample critical values of $\bar{z}_{1NT}$ by bootstrap in which the presence of serial correlation and contemporaneous correlation in residuals is allowed. A detailed discussion of the procedure of simulations is given in Appendix 1.

The JLR test provided by Taylor and Sarno (1998) is a special application of Johansen's (1988) maximum likelihood procedure for testing for the number of cointegrating vectors in a system. Under the null hypothesis that at least one of the series is a realization of a unit root process, the JLR test has a known limiting χ^2 distribution with one degree of freedom. To correct for small sample bias, we follow the method proposed by Taylor and Sarno (1998) to construct the 5% finite sample critical values. The discussion of the JLR test is not described here, but can be found in Taylor and Sarno (1998).

3. Empirical Investigation

3.1 Data Description

The empirical period begins in 1957M2 and follows through to 1999M4. Monthly observations of consumer price indices, which are not seasonally adjusted, are obtained from the International Monetary Fund's International Financial Statistic tape. We include 13 OECD countries in our sample: Belgium (BL), Canada (CN), Finland (FN), France (FR), Germany (GR), Italy (IT), Japan (JP), Luxembourg (LX), the

Netherlands (NT), Norway (NR), Spain (SP), the United Kingdom (UK) and the United States (US).

3.2 Unit-Root Tests

The conventional ADF test is applied to examine the unit-root null of inflation rates for each country. The model without a trend is adopted in the empirical analysis. We apply the recursive t-statistic procedure of Campbell and Perron (1991) to select the lag order of the ADF regression. Table 1 reports the P-value of the ADF test for inflation rates, which indicates that the unit-root null is rejected except for France, Japan, the Netherlands and Norway when the empirical period (1957M2 -- 1994M9) of Culver and Papell (1997) is applied. This finding is also consistent with that of Culver and Papell (1997) and is not significantly affected if the extended period (1957M2 -- 1999M4) is applied.

[Insert Table 1 Here]

It is well known that the ADF test has low power with a short time span as pointed out by Shiller and Perron (1985). Therefore, one possible reason for the failure of the ADF test to reject the unit-root null is the data's time span. We investigate this possibility by exploiting cross-section variability among countries. To do so, we apply the IPS test to re-examine the stationarity of inflation rates.

Taylor and Sarno (1998) and Karlsson and Lothgren (2000) point out that a rejection of the joint unit-root null can be driven by a few stationary series and the whole panel may erroneously be concluded as stationary. We therefore exclude those countries with stationary inflation rates at the 5% level of significance from our panel.[3] To correct for a small sample bias and to allow for the presence of serial correlation and contemporaneous correlation in innovations, we simulate the test's finite-sample critical values with a non-parametric bootstrap. We applied a block resampling algorithm in the bootstrap and set the block size to 16, 20, and 24, respectively. In the experiment 5,000 trials are used in computing the empirical size of the tests. Table 2 points out that the unit-root null of inflation rates is rejected at the 5% level of significance, which is robust to different block size and to different sample periods.

[Insert Table 2 Here]

It is interesting to ask whether the rejection of the unit root null is genuine, or is so because the bootstrap test tends to reject the null of the unit root even if the null is true. In other words, we are not clear whether the panel data bootstrap test adequately controls for size. This issue can be addressed by providing simulation evidence of the IPS test's reliability under the unit-root null. The evidence is provided in the form of a "bootstrap simulation" of the bootstrap test based on the best-fitting inflation rate model under the null hypothesis and fixing the sample size at the number of observations in the data set studied (see Appendix 2 for details). Findings from Table 2 point out that the size distortion of the bootstrap test ranges from 1.0% to 2.8% and it increases with the block size. Given the fact of the low P-value of the IPS test, we are safe to conclude that the unit-root null of inflation rates is rejected at the 5% level after taking into account the slight size distortion of the bootstrap test.

The rejection of unit-root null with the IPS test does not provide sufficient evidence to conclude that all series are stationary (Taylor and Sarno, 1998, and Karlsson and Lothgren, 2000). Following the suggestion of Taylor and Sarno (1998), we apply the JLR test to examine whether there is at least one non-stationary series in the panel.

To implement the JLR test, one needs to determine the optimal lag length in a VAR system. We apply the likelihood ratio test to determine the appropriate lag length of the VAR system. The selected lag length was 3 in both cases of the whole sample period and sub-sample period. Given the selected lag length, we then apply the JLR test to examine the null of having at least one non-stationary inflation rate in the panel. To correct for the small sample bias, we therefore construct the finite-sample critical values of the JLR test based on the method proposed by Taylor and Sarno (1998). Findings from Table 3 point out that the null of at least one non-stationary inflation rate is rejected by the JLR test at the 5% level of significance. In sum, findings from Tables 2 and 3 provide strong evidence to support the mean reversion of inflation rates.

[Insert Table 3 Here]

Contrary to the existing finding of a unit root in inflation rates, our finding rejects the unit-root null of inflation rates. This is interesting since it is consistent with the good monetary experience of most OECD countries. Although it has been argued that a better performance is possible, it is recognized that during the past 40 years there has been no major depression and no accelerating inflation involving a major currency. In addition, the finding of stationary inflation rates implies that it may not be appropriate to apply the conventional cointegration approach to analyze the Fisher effect (Mishkin, 1992) and the convergence of inflation rates (Artis and Nachane, 1990).

4. Conclusion

The conventional finding based on the ADF test points out that inflation rates are non-stationary. However, it is well known that the power of the ADF test is low when the time span is short. We increase the span of the data by extending the cross-sectional dimension of the data, and then examine the unit root null across a large number of inflation rates.

Two panel unit root tests provided by Im, Pesaran and Shin (1997) and Taylor and Sarno (1998), respectively, are applied to examine the mean reversion of inflation rates. The empirical findings from the previously mentioned two tests provide strong evidence to support that inflation rates in 13 OECD countries are mean reverting. This interesting finding implies that aggregate demand policies may not be over-implemented in the OECD countries since we fail to find evidence to support the accelerationist hypothesis. Our findings also point out that conventional cointegration analysis may not be appropriate in analyzing the Fisher effect and the convergence of inflation rates.

Endnotes

[1] The accelerationist hypothesis means that, to keep an unemployment rate below its natural rate, the authorities have to accept an ever-increasing level of inflation.

[2] The null hypothesis in Levin and Lin (1992, 1993) is $\phi_1 = \phi_2 = ... = \phi = 0$, and the alternative hypothesis is $\phi_1 = \phi_2 = ... = \phi < 0$. The alternative hypothesis may be restrictive in empirical analysis, because it means that each inflation rate reverts to its respective unconditional mean over time at the same rate.

[3] Findings from Table 2 are not affected if we exclude those countries with a stationary inflation rate at the 10% level of significance from our panel. Results are not reported here, but are available upon request.

Appendix 1

This appendix provides a detailed description of the bootstrap procedure.

1. We obtain the bootstrap sample of the error term $\eta_t^0 = [\eta_{1t}^0, \eta_{2t}^0, \cdots, \eta_{Nt}^0]$ by estimating the following system equations using the iterative seemingly unrelated regression (SUR) method:

$$y_{it} = \alpha_i + \beta_i y_{it-1} + \sum_{j=1}^{w_i} \gamma_{ij} \Delta y_{it-j} + \eta_{it}^0, \quad i = 1, ..., N,$$

where $\Delta y_{it} = y_{it} - y_{it-1}$. Term y_{it} has a unit root under the null of $\beta_i = 1$.

2. The block resampling procedure as described in Berkowitz and Kilian (1996) is applied to generate residuals for simulation. That is, we divide $\eta^0 = [\eta_1^0, ..., \eta_T^0]'$ into T-k overlapping blocks with length k+1 and randomly select a block with replacement, where $\eta_j^0 = [\eta_{1j}^0, ..., \eta_{Nj}^0]$, j=1,…,T. We first generate a pseudo-random number from the U(0,1) distribution and then use it to generate a random number integer h that takes on the value 1,…, T-k with equal probability. Once h is generated, we draw a block of fitted residuals $\overline{\eta}_1 = [\eta_h^0, ..., \eta_{h+k}^0]'$ to obtain $\overline{\eta}_1^*$. Repeating this operation m=T/(k+1) times yields a complete bootstrap sample of the error terms $\eta^* = [\overline{\eta}_1^*, ..., \overline{\eta}_m^*]'$. The bootstrap sample $y_{i,t}^*$ for $y_{i,t}$ is generated as

$$\Delta y_{it}^* = \sum_{j=1}^{w_i} \hat{\gamma}_{ij} \Delta y_{i\,t-j}^* + \eta_{it}^*,$$

where the $\hat{\gamma}_{ij}$'s are the SUR estimates obtained from step 1. The initial values of y_i^{0*}

are obtained by block resampling. That is, we divide y_{it} into T-k overlapping blocks and randomly select a block with a replacement for y_i^{0*}.

3. Compute the t values based on the following equation:

$$\Delta y_{it}^{*} = \delta_i + \phi_i y_{i\,t-1}^{*} + \sum_{j=1}^{w_i} \gamma_{ij} \Delta y_{i\,t-j}^{*} + \text{residual.}$$

4. Construct the t-bar statistic, $\bar{z}_{1NT}$, based on (2).

5. Repeat 2-4 steps 5,000 times to derive the empirical distribution of $\bar{z}_{1NT}$.

Appendix 2

This appendix gives a detailed description on constructing the size of the panel data bootstrap test. The idea is to nest two bootstrap procedures together.

1. We obtain the bootstrap sample of the error term $\eta_t^0 = [\eta_{1t}^0, \eta_{2t}^0, \cdots, \eta_{Nt}^0]$ by estimating the following system equations using the iterative SUR method:

$$y_{it} = \alpha_i + \beta_i y_{it-1} + \sum_{j=1}^{w_i} \gamma_{ij} \Delta y_{it-j} + \eta_{it}^0, \quad i = 1, ..., N,$$

where $\Delta y_{it} = y_{it} - y_{it-1}$. Term y_{it} has a unit root under the null of $\beta_i = 1$.

2. Following the second step of Appendix 1, we generate $y_{it}^{*,0}$ as follows:

$$\Delta y_{it}^{*,0} = \sum_{j=1}^{w_i} \hat{\gamma}_{ij} \Delta y_{it-j}^{*,0} + \eta_{it}^{*}.$$

We then construct the IPS statistic, $\bar{z}_{1NT}^0$, following the third and the fourth step in Appendix 1.

3. We obtain the bootstrap sample of the error term $\eta_t^1 = [\eta_{1t}^1, \eta_{2t}^1, \cdots, \eta_{Nt}^1]$ by estimating the following system equations with SUR.

$$y_{it}^{*,0} = \alpha_i^1 + \beta_i^1 y_{it-1}^{*,0} + \sum_{j=1}^{w_i} \gamma_{ij}^1 \Delta y_{it}^{*,0} + \eta_{it}^1, \quad i = 1, ..., N.$$

4. Repeating steps 2-4 in Appendix 1 for 500 times, we derive the empirical distribution of $\bar{z}_{1NT}$.

5. Comparing $\bar{z}_{1NT}^0$ with the 5% critical value from its empirical distribution, we can tell whether the unit-root null is rejected.

6. Repeating steps 2 to 5 for 1000 times, we construct the size of the panel data bootstrap test.

Table 1. P-Values of the ADF Test for Inflation Rate

		BL	CN	FN	FR	GR	IT	JP	LX	NT	NR	SP	UK	US
57:2-	k	12	11	11	15	11	14	13	11	14	13	11	13	16
94:9	PV	0.17	0.53	0.11	0.04*	0.06	0.28	0.04*	0.22	0.03*	0.03*	0.10	0.14	0.15
57:2-	k	16	11	11	11	11	14	13	11	14	15	11	13	16
99:4	PV	0.16	0.38	0.14	0.02*	0.07	0.27	0.04*	0.20	0.02*	0.07	0.11	0.13	0.12

Notes: 1. Term k is the lag order of the ADF test, which is selected based on the recursive procedure of Campbell and Perron (1991), while "PV" indicates the P-value of the ADF test.

2. * denotes the rejection of the unit-root hypothesis at the 5% level of significance.

Table 2. The Im-Pesaran-Shin Test for Inflation Rate

	$\bar{Z}_{1NT}$	BS	P-value	Critical Values 1%	5%	10%	Size
57:2-94:9	-2.690	16	0.018	-3.055	-2.069	-1.581	0.066
		20	0.022	-3.278	-2.163	-1.662	0.069
		24	0.025	-3.207	-2.238	-1.728	0.071
57:2-99:4	-3.120	16	0.013	-3.350	-2.190	-1.728	0.060
		20	0.012	-3.241	-2.207	-1.693	0.062
		24	0.018	-3.579	-2.315	-1.764	0.078

Notes: 1. $\bar{Z}_{1NT}$ is the test statistic of Im, Pesaran and Shin (1997).

2. "BS" is the size of block resampling.

3. P-values are constructed based on the bootstrapped distribution.

4. "Size" is the ratio of rejection of the unit-root hypothesis at a 5% normal critical value in the panel data bootstrap.

5. The panel includes inflation rates in Belgium, Canada, Finland, Germany, Italy, Luxembourg, Spain, the United Kingdom and the United States for the period of 57:2-94:9, and includes those of the same countries plus Norway for the period of 57:2-99:4.

Table 3. The JLR Test for Inflation Rates

	JLR	
57:2-94:9	9.380	(3.904)
57:2-99:4	10.543	(3.902)

Note: 1. Numbers in parentheses are 5% finite sample critical values which are constructed based on the method proposed by Taylor and Sarno (1998).

2. The panel includes inflation rates in Belgium, Canada, Finland, Germany, Italy, Luxembourg, Spain, the United Kingdom and the United States for the period of 57:2-94:9, and includes those of the same countries plus Norway for the period of 57:2-99:4.

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