Testing for Breaks in the Order of Integration of G7 Inflation and Interest Rates

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Introduction

- Stationarity of inflation is a key issue for policy-makers and is also important from the perspective of macroeconomic models that are specified on the presumption that a steady state exists
- Evidence of changing persistence properties based on tests for structural breaks is documented by Cecchetti and Debelle (2005), Levin and Piger (2004), Gadzinski and Orlandi (2004)
- This paper tests G7 inflation and interest rates for changes in persistence employing the tests of Harvey, Leybourne and Taylor (2006)
- Based on our Monte Carlo study, we extend the procedures to allow for possible structural breaks in the level of the series

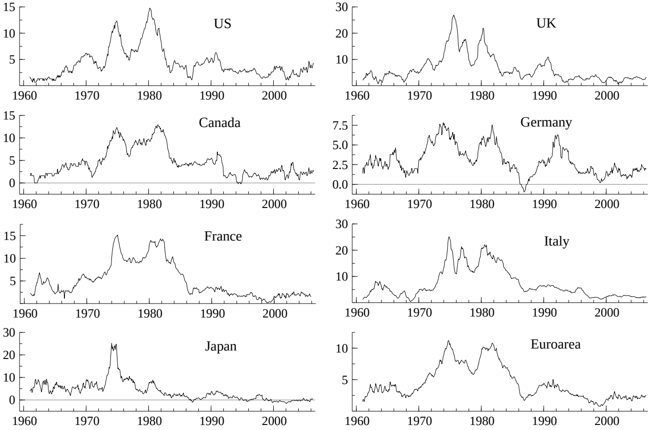

Fig. 1: Annual Inflation for G7 and Euro Area

Data and Preliminary Analysis

- Inflation: monthly G7 and European CPI (except for UK - RPI) over 1960:1-2005:12
- Seasonals dummies included in all regressions
- G7 interest rates: 3 month TB for US, UK, Canada and France; US Federal Funds rate; Interbank rate for Germany and Italy; Overnight lending rate for Japan
- Standard ADF and KPSS (Kwiatkowski et al, 1992) tests suggest that inflation is $I(1)$ over the whole sample period for all G7 countries
- Similar conclusion applies also to interest rates, with the exception of Germany, where the ADF test indicates that the series is $I(0)$
- Given the substantial changes in the monetary policy regimes, the properties of the series may also exhibit such shifts
- In the presence of a change in persistence, the ADF test will not diverge to $-\infty$, whereas the KPSS test will be consistent against such change

Testing for a change in persistence

- Kim et al (2002) and Busetti and Taylor (BT)(2004) develop tests for a change in persistence from $I(0)$ to $I(1)$ (or $I(1)$ to $I(0)$) under the null of a constant $I(0)$ process
- Leybourne et al (2004) propose such tests under the null of $I(1)$
- Modifications of the former tests by Harvey, Leybourne and Taylor (HLT)(2006) and of the latter by Leybourne et al (2004) allow the null to be either $I(1)$ or $I(0)$

Tests developed under an $I(0)$ null

$$
\begin{aligned}
y_t &= d_t + \mu_t + \varepsilon_t, \quad \varepsilon_t \sim iid(0, \sigma^2) \\
\mu_t &= \mu_{t-1} + 1\left(t > [\tau^* T]\right) \eta_t, \quad \eta_t \sim iid(0, \sigma_\eta^2)
\end{aligned}
$$

y_t is $I(0)$ for $t = 1, ..., [\tau^* T]$ but changes to $I(1)$ after time $[\tau^* T]$

- Kim et al (2002) and Busetti and Taylor (2004) develop the following ratio-based statistic for a change from $I(0)$ to $I(1)$

$$
\mathcal{K}_\tau = \frac{(T - [\tau T])^{-2} \sum_{t=[\tau T]+1}^{T} \left(\sum_{s=[\tau T]+1}^{t} \hat{\varepsilon}_{1,s} \right)^2}{([\tau T])^{-2} \sum_{t=1}^{[\tau T]} \left(\sum_{s=1}^{t} \hat{\varepsilon}_{0,s} \right)^2} \tag{1}
$$

$$
\begin{aligned}
MX &\equiv \sup_{\tau \epsilon \mathcal{F}} \mathcal{K}_\tau \\
ME &\equiv \ln \left\{ \int_{\tau \in \mathcal{F}} \exp\left(\frac{1}{2} \mathcal{K}_\tau \right) d\tau \right\}
\end{aligned}
$$

- MX and ME are inconsistent against a change from $I(1)$ to $I(0)$ (BT, 2004)
- BT (2004) propose simple modifications which reverse the numerator in $\mathcal{K}_\tau$ (denoted MX^R and ME^R)

- Since the break-point τ^* is unknown, Kim et al (2002) propose estimating τ^* for a change from $I(1)$ to $I(0)$ as

$$\begin{aligned} \hat{\tau} &= \arg\min_{\tau \in \mathcal{F}} \Lambda(\tau) \\ \Lambda(\tau) &= \frac{([\tau T])^2 \sum_{t=[\tau T]+1}^{T} \hat{\varepsilon}_{1,t}^2}{([(1-\tau)T])^2 \sum_{t=1}^{[\tau T]} \hat{\varepsilon}_{0,t}^2} \end{aligned} \quad (2)$$

- For a change from $I(0)$ to $I(1)$, they propose

$$\tilde{\tau} = \arg\max_{\tau \epsilon \mathcal{F}} \Lambda(\tau) \quad (3)$$

- Previous statistics are designed to test under $I(0)$ null and are $O_p(1)$ when the process is $I(1)$
- HLT (2006) propose tests for H_0 of constant persistence (either $I(0)$ or $I(1)$) vs. H_A of a change from $I(0)$ to $I(1)$

$$MX_m = \exp(-bJ_{1,T})MX \tag{4}$$

where $J_{1,T} = T^{-1} \times Wald \;\; statistic$ for testing $\gamma_{k+1} = ... = \gamma_9 = 0$

$$y_t = x_t'\beta + \sum_{i=k+1}^{9} \gamma_i t^i + u_t, \quad t = 1, ..., T \tag{5}$$

where $x_t = 1 \; (k = 0)$ or $x_t = \left(1, t, .., t^k\right)'$.

- Further, HLT (2006) propose

$$MX_{m\min} = \exp(-bJ_{\min})MX \qquad (6)$$

where $J_{\min} = \min_{\tau\epsilon\mathcal{F}} J_{1,[\tau T]}$, where $J_{1,[\tau T]}$ is T^{-1} times the Wald statistic $\gamma_{k+1} = .. = \gamma_9 = 0$ in

$$y_t = x_t'\beta + \sum_{i=k+1}^{9} \gamma_i t^i + u_t, \quad t = 1, ..., [\tau T]$$

- Analogues modifications are proposed by HLT (2006) for ME_m, MX_m^R, ME_m^R, ME_{mmin}, MX_{mmin}^R, ME_{mmin}^R

Testing in the presence of a deterministic structural break

- Neglecting structural breaks may have important implications for tests on changes in persistence
- Perron (1989) showed that the existence of a break in the deterministic component of an I(0) process can lead to non-rejection of the null of the standard unit root test
- Zivot and Andrews (1992) propose tests for the unit root null hypothesis allowing for a structural break in the deterministic component at an unknown time
- Lee and Strazicich (2004) propose a test for unit root allowing for a deterministic break at unknown timing under both the null and alternative hypotheses

Allowing for a determinisitic break in persistence change tests

- Extend the analysis of Busetti and Taylor (2004) and Harvey et al (2006) allowing for a level shift in the series estimated exogenously from the data
- The unknown break point in the level is estimated using Bai (1997) procedure

$$\hat{\lambda} = \arg\min_{\lambda \in \Lambda} \sum_{t=1}^{T} \tilde{\varepsilon}_t^2$$

where $\tilde{\varepsilon}_t$ is the residual from the regression of y_t on an intercept and $1\left(t \leq [\lambda T]\right)$ for $t = 1, ..., T$, $\lambda \in \Lambda$.

- The tests of BT (2004) and HLT (2006) are modified by employing instead of $\hat{\varepsilon}_{0,t}$ and $\hat{\varepsilon}_{1,t}$

$$\tilde{\varepsilon}_{0,t} = y_t - x_t'\tilde{\beta}_0 - \tilde{\delta}_0 1\left(t \leq [\hat{\lambda}T]1(\tau > \hat{\lambda}\right), \ \ t = 1, ..., [\tau T] \quad (7)$$

$$\tilde{\varepsilon}_{1,t} = y_t - x_t'\tilde{\beta}_1 - \tilde{\delta}_1 1\left(t \leq [\hat{\lambda}T]1(\tau < \hat{\lambda}\right), \ \ t = [\tau T] + 1, ..., T \quad (8)$$

Monte Carlo Analysis

$$y_t = 0.5 + \delta 1\left(t \leq [\lambda T]\right) + \varepsilon_t \text{ ,} \varepsilon_t \sim N(0,1) \quad (9)$$

$T = 500,\ R = 10000,\ \delta \in \{0.3, -1.5\},\ \lambda \in \{0.3, 0.5, 0.7\}$

Table 4. Empirical rejection frequencies for tests of change in persistence in the presence of a level shift when the null of $I(0)$ is true

δ	0.3	0.3	0.3	-1.5	-1.5	-1.5
λ	0.3	0.5	0.7	0.3	0.5	0.7
MX^R	35.39	29.96	6.02	100	99.9	90.60
MX_m^R	34.86	29.35	5.89	99.9	99.9	87.00
$MX_{m\min}^R$	34.56	29.11	5.83	100	99.98	89.77
MX	1.64	19.20	37.72	7.24	99.69	99.99
MX_m	1.61	18.67	37.16	5.02	99.38	99.98
$MX_{m\min}$	1.59	18.58	36.99	6.80	99.61	99.99

Table 5. Empirical rejection frequencies for tests of a change in persistence allowing for a level shift when the null is true

$$y_t = 0.5 + \delta 1\left(t \leq [\lambda T]\right) + \varepsilon_t,\ \ \varepsilon_t \sim N\left(0, 1\right)$$

δ	0.3	0.3	0.3	-1.5	-1.5	-1.5	0
λ	0.3	0.5	0.7	0.3	0.5	0.7	-
MX^R	2.42	4.75	7.43	1.82	4.79	8.06	2.41
MX^R_m	2.38	4.64	7.28	1.78	4.71	7.88	2.35
$MX^R_{m\,\min}$	2.28	4.49	7.11	1.72	4.64	7.64	2.29
MX	7.38	4.80	2.27	7.96	4.71	1.82	2.93
MX_m	7.29	4.68	2.21	7.82	4.54	1.80	2.84
$MX_{m\,\min}$	7.08	4.54	2.12	7.66	4.43	1.74	2.78

Table 9. Tests for a change in persistence for G7 and European inflation under the null of a $I(0)$ process

	US	UK	CAN	GER	FR	IT	JP	EA
$\hat{\tau}$	1982:2	1981:4	1975:7	1974:2	1984:7	1985:12	1976:12	1983:1
MX^R	250.13^a	467.37^a	81.94^a	7.20	150.73^a	27.01^b	39.00^a	45.64^a
ME^R	119.66^a	228.29^a	36.11^a	1.61	70.75^a	9.25^b	14.90^a	17.90^a
MX_m^R	205.57^b	375.88^b	69.40^b	6.80	94.88^b	15.10	34.92^b	32.68^b
ME_m^R	93.47^b	173.52^b	29.30^b	1.50	39.50^b	4.45	12.97^b	11.76^b
$MX_{m\min}^R$	236.75^b	450.60^b	80.25^b	6.67	144.71^b	17.30	37.06^b	42.73^b
$ME_{m\min}^R$	112.09^b	218.58^b	35.24^b	1.47	67.40^b	5.45^b	14.02^b	16.55^b
$\tilde{\tau}$	1992:3	1973:12	1990:9	1991:6	1973:12	1973:10	1991:9	1990:7
MX	4.10	10.12	7.46	2.17	20.97^b	43.94^a	21.03^b	9.46
ME	0.34	1.39	0.81	0.34	5.67^b	16.64^a	5.22^b	1.12
MX_m	3.37	8.13	6.32	2.05	13.19	24.52^b	18.83^b	6.77
ME_m	0.26	1.06	0.66	0.32	3.17	8.01^b	4.54	0.73
$MX_{m\min}$	2.51	7.66	6.09	1.81	16.81	25.86^b	19.69^b	6.40
$ME_{m\min}$	0.18	1.00	0.64	0.27	4.36	8.85^b	4.82	0.70

Note: ^{a},^{b},^{c} denote significance at the 1%, 5% and 10%

Table 10. Tests for a change in persistence for G7 and European inflation under $I(0)$ null taking account of a structural break in the mean

	US	UK	CAN	GER	FR	IT	JP	EA
$\hat{\lambda}$	1982:7	1990:10	1991:1	1982:11	1985:7	1985:12	1981:6	1985:4
$\hat{\tau}$	1974:12	1981:4	1975:7	1973:11	1974:10	1982:11	1974:11	1974:11
MX^R	363.15^a	484.09^a	189.07^a	13.04	234.71^a	37.68^a	9.87	71.02^a
ME^R	176.17^a	236.65^a	89.38^a	4.34	112.47	14.32^a	2.80	30.44^a
MX_m^R	301.92^b	410.15^b	168.44^b	12.54	187.10^b	25.07^b	9.58	58.03^b
ME_m^R	139.62^b	192.08^b	77.28^b	4.14	84.54^b	8.57^b	2.70	23.61^b
$MX_{m\,\min}^R$	343.72^b	474.44^b	185.18^b	12.08	225.33^b	24.13^b	9.38	66.50^b
$ME_{m\,\min}^R$	165.02^b	229.88^b	87.20^b	3.97	107.15^b	8.42^b	2.64	28.15^b
$\tilde{\tau}$	1992:3	1973:12	1990:7	1991:5	1990:7	1973:11	1991:9	1990:7
MX	0.09	1.43	0.59	0.97	0.21	1.11	1.25	0.17
ME	0.02	0.05	0.03	0.15	0.02	0.05	0.19	0.03
MX_m	0.08	1.21	0.53	0.93	0.17	0.74	1.22	0.13
ME_m	0.01	0.04	0.03	0.15	0.01	0.03	0.19	0.02
$MX_{m\,\min}$	0.06	1.08	0.48	0.81	0.17	0.66	1.17	0.11
$ME_{m\,\min}$	0.01	0.03	0.03	0.13	0.01	0.02	0.18	0.02

Note: ^{a},^{b},^{c} denote significance at the 1%, 5% and 10%

Results for Interest Rates

- A change from $I(1)$ to $I(0)$ for UK, Canada, France, Italy and Japan
- A change from $I(0)$ to $I(1)$ for all countries, except Italy
- US interest rates has been stationary, but allowing for a mean break, US IR change from $I(1)$ to $I(0)$ in 1982:7
- The mean break for UK is 1992:9, with a break in persistence dated in 1982:5
- The dates for the mean breaks are around early to mid-1990s, except for Italy
- Significant changes from $I(1)$ to $I(0)$ (except, for Germany and Italy) occur earlier than the mean breaks, namely in the early to mid-1980s

Conclusions

- There is a change in inflation persistence from $I(1)$ to $I(0)$ for all countries, except for Germany
- The results for changes in persistence take account of possible break in the mean
- The dated break in mean for UK and Canada is close to the introduction of inflation targeting and the date for the change in persistence does not change
- For the inflation series, when allowing for a mean shift, the changes from $I(1)$ to $I(0)$ are documented earlier in the sample
- The change from $I(0)$ to $I(1)$ for France and Italy dissapears after taking account of the break in mean
- For interest rate series, most countries exhibit a change in persistence behaviour, but the change occurs later than for inflation
- For both series, estimated mean shifts almost always occur after the change to stationarity

Research Agenda

- Develop tests for a change in persistence allowing for breaks in the deterministic component at unknown timing
- Develop tests for structural breaks in the mean allowing for a change in persistence at unknown timing
- Extend the analysis allowing for multiple breaks in the deterministic components