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Aggregate output dynamics in the twentieth century

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Abstract

This study shows that annual output data of the G7 countries in the twentieth century are better characterized as transitory deviations from a (shifting) growth trend than as integrated processes. Furthermore, I find no two countries share common business cycles.

JEL classification: C22, E32, O57

1. Introduction

The issue of output persistence has received considerable attention since Nelson and Plosser (1982) reported that aggregate output data, among many other macroeconomic and financial data, do not reject the unit root hypothesis. Subsequent studies on this issue include Stock and Watson (1986), Campbell and Mankiw (1987, 1989), Cochrane (1988), Clark (1989), Diebold and Rudebusch (1989), and Cogley (1990). Output persistence has significant implications for both the theory and practice of macroeconomics. For example, models that describe output fluctuations as temporary deviations from the long-run growth trend are not consistent with the evidence of permanent shocks in output data. For policy-makers, countercyclical policies are more appropriate when variations in output are largely transitory movements around the trend than when variations are mainly permanent.

Recently, Nelson and Plosser's conclusion on output persistence has been re-examined from various perspectives. Christiano and Eichenbaum (1990), Stock (1991), and Rudebusch (1992) show that standard techniques have a low power to discriminate between the hypotheses of trend- and difference-stationarity for the US macroeconomic data. DeJong and Whiteman (1991) attribute the unit root result to a prior that assigns a low probability to trend-stationary alternatives. Using tests that allow for structure changes, Perron (1989, 1990) finds less favorable evidence of unit roots. However, as pointed out by Christiano (1992), Perron's approach is biased in favor of the structural break alternative as the test does not account for the effect of assuming a known date of break. Christiano (1992) and Zivot and Andrews (1992) find more favorable evidence of unit roots than Perron did after controlling for the bias of choosing the break point.

Recently, Banerjee, Lumsdaine and Stock (henceforth referred to as 'BLS') (1992) developed unit root tests that allow for unknown break points in the time series. An advantage of the BLS tests is that they are not subjected to Christiano's criticism as these tests are not conditional on a pre-assigned break point and, hence, provide an objective evaluation of the unit root and stationarity with structural breaks hypotheses.

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In this study we first use the BLS procedures to test for possible deterministic shifts in the real per capita gross domestic product (GDP) of the Group of Seven (G7) countries over the period 1900–1990. Then, following Campbell and Mankiw (1989), we examine whether 'all business cycles are alike'. The common feature test developed by Engle and Kozicki (1993) is used to investigate comovements in the transitory components of these GDP data.

In section 2 we introduce the BLS recursive and sequential unit root tests and report the test results. The ARMA representations for the transitory output and the results of the common feature test are presented in section 3. Section 4 summarizes the paper.

2. Recursive and sequential tests for unit roots

2.1. Recursive and sequential tests

Suppose y_t, the log real per capita GDP, has an AR($p + 1$) representation:

$$y_t = \mu_0 + \mu_1 t + \alpha_1 y_{t-1} + \cdots + \alpha_{p+1} y_{t-p-1} + \epsilon_t , \tag{1}$$

where ϵ_t is the error term and $t = 1, \ldots, T$. Rearranging terms, we have

$$\Delta y_t = \mu_0 + \mu_1 t + \alpha y_{t-1} + \beta_1 \Delta y_{t-1} + \cdots + \beta_p \Delta y_{t-p} + \epsilon_t , \tag{2}$$

where Δ is the difference operator defined by $\Delta y_t \equiv y_t - y_{t-1}$. The standard Dickey–Fuller (D–F) test for the unit root hypothesis computes τ, the regression t-statistic for α, over the whole sample and compares it with the critical values tabulated in Fuller (1976). On the other hand, the BLS recursive test is based on the sequence of regression t-statistics, $\tau(k)$, from the samples $(1, \ldots, k)$; $k_0 \le k \le T$. The trimming parameter k_0 determines the sample size used to initialize the recursive procedure. Intuitively, $\tau(k)$ provides information on whether only part of the series contains a unit root. In this study, the minimal D–F statistic, $\tau_M \equiv \min_{k_0 \le k \le T} \tau(k)$, and the range of the D–F statistic, $\tau_R = \max_{k_0 \le k \le T} \tau(k) - \tau_M$, are used.

The BLS sequential test considers the following model:

$$\Delta y_t = \mu_0 + \mu_1 t + \mu_2 d_t(k) + \alpha y_{t-1} + \beta_1 \Delta y_{t-1} + \cdots + \beta_p \Delta y_{t-p} + \epsilon_t , \tag{3}$$

where $d_t(k)$ is a dummy variable. When a shift in the trend at time k is considered under the alternative, $d_t(k)$ is set equal to $(t-k)I(t > k)$, where $I(\cdot)$ is the indicator function. Alternatively, when a break in the trend at time k is considered, $d_t(k)$ is set equal to $I(t > k)$. Following BLS, we label the former situation as case A and the latter as case B. For case A, we compute three sequential statistics. They are (1) $F_{A,\max} \equiv \max_{k_0 \le k \le T-k_0} F(k)$, (2) $\tau_A(\hat{k})$, where $F(\hat{k}) = F_{A,\max}$, and (3) $\tau_{A,M} \equiv \min_{k_0 \le k \le T-k_0} \tau_A(k)$. $F(k)$ and $\tau_A(k)$ are, respectively, the F-statistic for the hypothesis of $\mu_2 = 0$ and the D–F t-statistic computed from the whole sample with $d_t(k)$ defined as above. For case B, we also compute the similar statistics and label them as $F_{B,\max}$, $\tau_B(\hat{k})$,and $\tau_{B,M}$.

The asymptotic distributions of the recursive and sequential tests are derived in BLS (1992). These authors also tabulated the finite sample critical values using Monte Carlo simulation methods and showed that these tests have good empirical size and power.

2.2. The data

The log real per capita GDP of the G7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States) are examined. The sample period is 1900–1990. Annual

GDP data from 1900 to 1987 and the population data from 1900 to 1979 are obtained from Maddison (1982, 1989). The recent data are from the OECD *Main Economic Indicators*.

The seven output data series are graphed in Fig. 1. These graphs reveal that each of these countries may have had a deterministic change in its growth path during the twentieth century. For Canada, the United Kingdom, and the United States the economic build-up after the Great Depression appears to have sparked a permanent change in the trend growth. The remaining four countries seem to have experienced a permanent change in the growth trend after the Second World War. In the following subsection, we present results of formal tests for permanent shifts in these data series.

2.3. Empirical evidence

The order of the AR polynomial, p, and the trimming parameter, k_0, are required to implement the BLS tests. As unit root tests are sensitive to serial dependence in the error term, we want to choose a lag parameter p large enough to capture the possible serial correlation in the data. Based on the longest duration of the US business cycles in this period, we set $p = 8$. Results obtained, for example, with $p = 4$ and $p = 10$ are similar to those reported below. For the trimming parameter k_0, we follow BLS to set $k_0 = 22$ for the recursive test and $k_0 = 13$ for the two sequential tests.

The results of the standard, recursive, and sequential D–F tests are presented in Table 1. Consistent with previous studies, the standard D–F test does not reject the unit root hypothesis for each of these seven countries. However, the recursive and sequential statistics yield substantially less evidence of unit roots. For instance, all the recursive statistics, τ_R's, are significant at the 5% level. The sequential test statistics indicate that there is stronger evidence for the trend-break alternative than the trend-shift alternative. However, for the sample size considered, the test may have little power against small and moderate shifts in the trend. The estimated break point, which is the k that maximizes $F(k)$, is given below the $F_{A,max}$ and $F_{B,max}$ statistics. These estimated break points are similar to those obtained from visual inspection of the data. Overall, the results suggest that, during the twentieth century, the GDP of these countries are better characterized as transitory fluctuations along a trend path that exhibits deterministic changes than as integrated processes.

As demonstrated by Schwert (1989), underparametrization can adversely affect unit root tests and high-order AR approximations usually give better results. We use the serial correlation pattern of the residuals from the sequential regressions to investigate if we underparametrized p. In all cases, the Box–Ljung Q-statistic indicates no significant serial dependence in the first 10 and 20 lags of these estimated residuals. That is to say, our choice of p adequately captures the serial pattern in these output data.

3. Dynamics of cyclical components

Given the evidence reported in section 2, we define x_t, the transitory component of the output series, by

$$y_t = \mu_0 + \mu_1 t + \mu_2 d_{A,t}(\hat{k}_A) + \mu_3 d_{B,t}(\hat{k}_B) + x_t \,, \qquad (4)$$

where $d_{A,t}(\hat{k}_A) = (t - \hat{k}_A)I(t > \hat{k}_A)$, $d_{B,t}(\hat{k}_B) = I(t > \hat{k}_B)$, and $\hat{k}_A$ and $\hat{k}_B$ are estimated break points reported in Table 1. We include both $d_{A,t}(\hat{k}_A)$ and $d_{B,t}(\hat{k}_B)$ in (4) to avoid possible

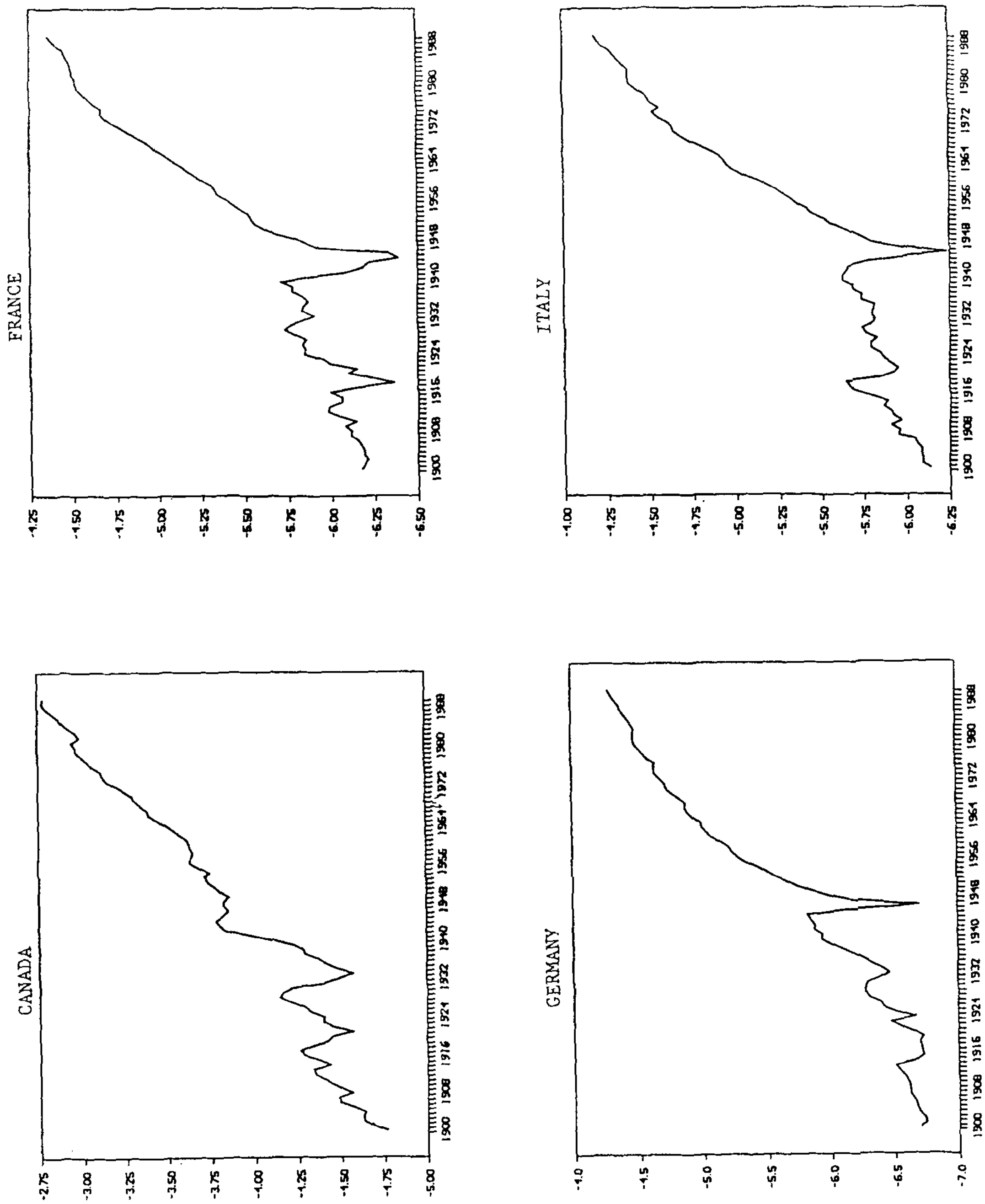

Fig. 1. Log real per capita GDP, 1900–1990.

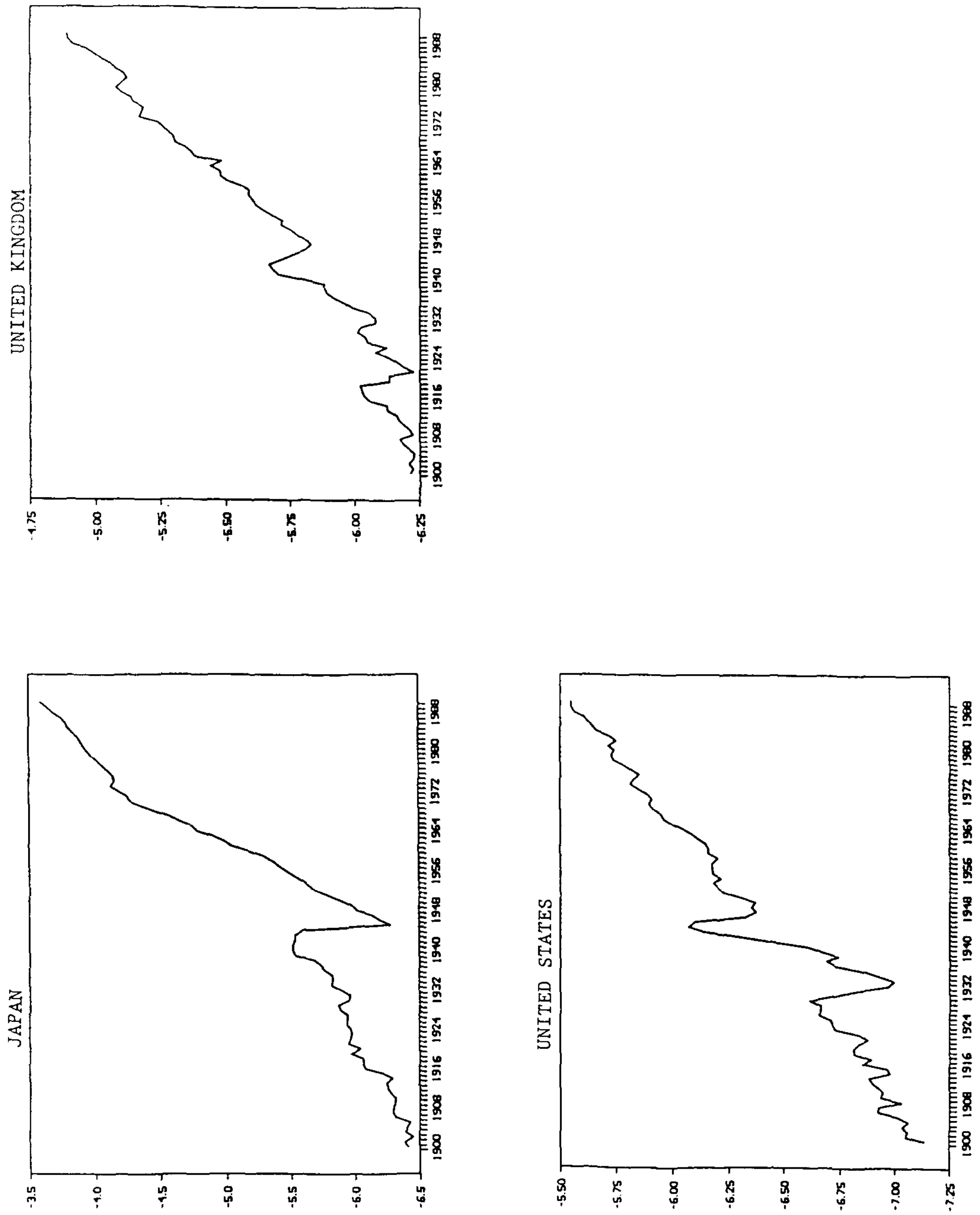

Fig. 1. *(Continued)*

Table 1
Results of recursive and sequential unit root tests

	CA	FR	GE	IT	JA	UK	US
τ	−1.516	−1.629	−2.416	−1.238	−1.380	−1.561	−3.258
τ_M	−4.888[a]	−4.424[b]	−2.807	−3.639	−6.228[a]	−7.185[a]	−14.02[a]
τ_R	7.542[a]	4.049[a]	3.662[a]	5.608[a]	5.697[a]	7.335[a]	13.49[a]
$F_{A,max}$	29.27[a]	10.05	2.740	14.28[b]	10.79	11.56	12.35
$\hat{k}_A$	1933	1943	1915	1945	1946	1931	1932
$\tau_A(\hat{k}_A)$	−5.659[a]	−3.672	−3.116	−4.040	−3.593	−3.843	−5.115[a]
$\tau_{A,M}$	−5.659[a]	−3.672	−3.116	−4.040	−3.593	−3.843	−5.119[a]
$F_{B,max}$	17.34[b]	18.77[a]	20.88[a]	32.04[a]	12.84	17.61[b]	12.73
$\hat{k}_B$	1918	1945	1947	1946	1946	1919	1930
$\tau_B(\hat{k}_B)$	−4.001	0.712	−2.983	0.957	0.832	−4.355	−5.156[a]
$\tau_{B,M}$	−4.165	−3.145	−4.878[a]	−2.909	−2.884	−4.355	−5.156[a]

The table represents results of the recursive and sequential unit root tests on the annual log real per capita GDP of Canada (CA), France (FR), Germany (GE), Italy (IT), Japan (JA), the United Kingdom (UK), and the United States (US) over the period 1900–1990. See the text for a more detailed discussion of the test statistics. Results are based on lag $p = 8$.
[a]Rejection of the unit root hypothesis at the 5% level.
[b]Rejection of the unit root hypothesis at the 10% level.

omission of relevant variables and let the data determine the significance of each variable. Regression results (not reported) show that, based on standard errors that are robust to both serial correlation and heteroskedasticity, most parameter estimates are significant. The adjusted R^2 from regression (4) ranges from 0.950 (France) to 0.986 (the United Kingdom).

To shed some light on the time series dynamics of transitory output, we estimate an ARMA model for each of the transitory component series. All ARMA models with AR and MA lags less than four are considered. The Schwartz Bayesian Criterion (SBC) is used to select the model specification. Maximum likelihood estimation results are reported in Table 2. The Box–Ljung Q-statistic indicates no significant serial correlations in the estimated residuals. It is noted that all

Table 2
ARMA representations for transitory output components

	CA	FR	GE	IT	JA	UK	US
ϕ_1	1.247	0.749	0.722	1.078	0.739	0.794	1.185
	(0.093)	(0.080)	(0.085)	(0.101)	(0.074)	(0.064)	(0.095)
ϕ_2	−0.463			−0.290			−0.421
	(0.093)			(0.101)			(0.095)
θ_1		−0.460	−0.381				
		(0.105)	(0.113)				
$\bar{R}^2$	0.775	0.761	0.713	0.710	0.527	0.625	0.744
$Q(10)$	14.82	10.23	2.23	3.45	4.69	13.40	8.82
$Q(20)$	16.14	24.41	6.53	10.49	11.44	21.23	13.56

The table represents the ARMA models for the transitory output of the G7 countries selected by the Schwert Bayesian Criterion. The model considered is $x_t = \phi_1 x_{t-1} + \cdots + \phi_p x_{t-p} + \epsilon_t - \theta_1 \epsilon_{t-1} - \cdots - \theta_q x_{t-q}$. Standard errors are reported in parentheses. $\bar{R}^2$ reports the adjusted R^2. $Q(10)$ and $Q(20)$ are the Box–Ljung statistics computed from the first 10 and 20 autocorrelations of the estimated residuals.

AR(1) parameter estimates are positive. However, with the exceptions of the Canada–US, France–Germany, and Japan–UK pairs, no other two countries display similar ARMA estimates. Thus, for 18 out of 21 pairs of countries, national business cycles are not likely to be the same. Models selected by the Akaike Information Criterion, which tends to give higher order ARMA models, are more diverse than those selected by the SBC and provide less evidence of similar business cycles across the G7 countries.

The estimated ARMA models provide only an imprecise comparison of national business cycles. The common feature test developed by Engle and Kozicki (1993) represents a formal procedure to examine if there exists a common serial correlation pattern in any pair of these countries. The intuition behind the common feature analysis is as follows. Suppose the temporal relations of both x_{it} and x_{jt}, the transitory output of countries i and j, are driven by a common stochastic process. The effect of this common stochastic component can be removed by choosing an appropriate linear combination of x_{it} and x_{jt}. Thus, statistical inference about the presence of this common temporal relation can be drawn from the behavior of linear combinations of the variables. To conduct the test for common serial correlations, we first estimate

$$x_{it} = c + \delta x_{jt} + \omega_t \,, \tag{5}$$

with the instrument variables $\{c, \Omega_{t-1}\}$, where $\Omega_{t-1} \equiv (x_{it-k}, x_{jt-k};\ k = 1, \ldots, p))$. $(1, \delta)$ is the normalized common feature vector. Then, we compute the TR^2 statistic from the regression of $\hat{\omega}_t$ on Ω_{t-1}. Under the null hypothesis of a common serial correlation feature relative to the information set Ω_{t-1}, the TR^2 statistic has an asymptotic $\chi^2(2p-1)$ distribution.

Table 3 presents the common feature test results based on $p = 8$. Similar results were obtained for other values of p. Column 1 contains the TR^2 statistic from the test with country i as the dependent variable in (5). The null hypothesis of a common correlation pattern is clearly rejected in all cases. Each country has a unique element in its cyclical movements that is not shared with other countries for the entire sample period. For the cases of Canada–US, France–Germany, and Japan–UK, the similarity in ARMA parameter estimates is not related to common business cycle movements. Our results strengthen those reported in Campbell and Mankiw (1989), who use a different technique and find no evidence of 'all business cycles are alike' in the output data of the same G7 countries over the period 1957–1986.

Table 3
Results of the common feature test

	CA	FR	GE	IT	JA	UK	US
CA		62.262	66.789	67.251	66.230	68.1637	57.534
FR	61.966		63.095	61.173	59.636	67.5742	59.553
GE	63.358	64.482		43.525	65.486	61.0542	63.745
IT	60.877	58.097	40.097		49.208	60.5736	59.819
JA	51.915	49.492	47.118	46.109		46.3951	54.495
UK	63.263	61.291	54.508	57.006	51.271		68.267
US	57.941	60.379	65.785	63.990	68.607	67.7544	

Results of the test for a common serial correlation feature in a pair of G7 countries are reported. The lag parameter is set to 8. Column i (i = CA, FR, GE, IT, JA, UK, and US) presents the TR^2 statistic, which has an asymptotic $\chi^2(15)$ distribution under the null of a common serial correlation feature, from the test with country i as the left-hand-side variable in the first stage of the test. The null is rejected for all cases.

4. Summary

Using the recently developed recursive and sequential tests for unit roots, we reject the unit root hypothesis for the log real per capita GDP of the G7 countries in the twentieth century. The test results suggest that changes in the trend occurred after the Great Depression for Canada, the United Kingdom, and the United States and after the Second World War for France, Germany, Italy, and Japan. Output variations in other periods are mainly temporary in nature. Our evidence is consistent with the conventional view that output fluctuations are temporary deviations from the growth trend. As the break point in the trend path is determined endogenously and not fixed using priori information, our results are not subject to the data-mining criticism. Furthermore, the transitory output components of the G7 countries appear to exhibit different cyclical movements in the twentieth century. The test for a common serial correlation feature suggests that no two countries share common business cycles for the entire sample period.

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