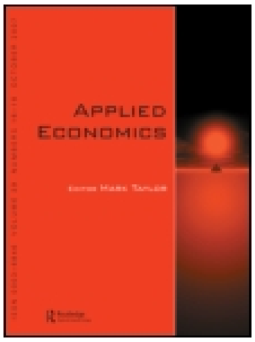

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How great are the great ratios?

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The balanced growth and neoclassical stochastic growth literatures imply stationarity of certain macroeconomic 'great ratios'. Four such ratios are considered: consumption:output, investment:output, the real interest rate and real money supply growth, and evidence for ratio stationarity in the G7 countries is examined. Univariate unit root and stationarity tests are performed, and analysis of the cointegrating relations between output, consumption and investment is conducted. Almost no evidence of stationarity is found for the consumption:output and investment:output great ratios. Empirical evidence supports real money supply growth stationarity, but is more mixed for the real interest rate.

I. INTRODUCTION

The balanced growth literature (for example Klein and Kosobud, 1961) postulates a number of 'great ratios' of macroeconomic variables which should exhibit stability over time. The most celebrated of these are the consumption:output and investment:output ratios. Introduction of the neoclassical stochastic growth model under uncertainty (Brock and Mirman, 1972; Donaldson and Mehra, 1983) extended this concept. The neoclassical framework is one in which productivity shocks are permanent and constitute the driving force behind the bulk of economic fluctuations. The key long-run implication is that a common stochastic trend exists with output, consumption and investment following a common growth path. This result is consistent with the balanced growth hypothesis and implies that the consumption:output and investment:output ratios are stationary stochastic processes (see King *et al*., 1988), i.e. consumption and investment are cointegrated with output. Two other relations which can also be thought of as great ratios, and appear in much of the real business cycle literature (for example King *et al*., 1991), are the real interest rate and real money supply growth.

This paper is concerned with whether evidence exists in favour of stationarity for these four ratios: consumption: output, investment:output, the real interest rate and real money supply growth. The study builds on work by Kunst and Neusser (1990), King *et al*. (1991), Neusser (1991), Serletis (1994) and Serletis and Krichel (1995), and examines empirically the statistical properties of the great ratios for the G7 countries. Univariate analysis is performed on the constructed ratios to examine whether they are stationary, and multivariate techniques are used to examine the presence of cointegration in a system involving output, consumption and investment. Almost no evidence is found for stationarity of the consumption:output and investment:output ratios internationally, and likewise no empirical support is found for the great ratios cointegration restriction in the trivariate framework. Evidence for real interest rate stationarity is mixed, and strong support is found for the stationary behaviour of real money supply growth in the countries considered.

Section II provides the theoretical background to the study and describes the data we use; Sections III and IV present the univariate and multivariate empirical analyses respectively. The paper is concluded in Section V.

II. BACKGROUND AND DATA

The theoretical background to the analysis builds on the growth theory due to Solow (1956). In the basic

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neoclassical model, the one-sector economy can be described by a constant returns to scale Cobb–Douglas production function

$$Y_t = \lambda_t K_t^{1-\alpha} N_t^{\alpha} \tag{1}$$

where Y_t is output, K_t the capital stock, N_t labour input and λ_t total factor productivity. Inclusion of a deterministic trend in λ_t of the form

$$\log(\lambda_t) = \mu_\lambda + \log(\lambda_{t-1}) \tag{2}$$

leads to, under suitable assumptions concerning preferences, capital accumulation and resource constraints, a result of steady state growth. Per capita output, consumption and investment then share a common growth rate μ_λ/α and the great ratios C_t/Y_t and I_t/Y_t are constant.

This deterministic system was adapted by Brock and Mirman (1972) and Donaldson and Mehra (1983) to form the neoclassical stochastic growth model under uncertainty. Total factor productivity is now characterized by

$$\log(\lambda_t) = \mu_\lambda + \log(\lambda_{t-1}) + \xi_t \tag{3}$$

where $\xi_t \sim \mathrm{IID}(0, \sigma^2)$. Balanced growth again follows and the common growth rate is $(\mu_\lambda + \xi_t)/\alpha$. The logarithms of output, consumption and investment are thus integrated of order one, share a common stochastic trend, and the logarithmic great ratios $c_t - y_t$, $i_t - y_t$ now follow stationary stochastic processes. Clearly c_t and i_t are respectively cointegrated with y_t in this framework.

It is also interesting to investigate the properties of two other great ratio type relations, given their importance in real business cycle modelling. These are logarithmic real money supply growth $\Delta(m_t - p_t)$ and the real interest rate $R_t - \Delta p_t$. (The real interest rate is not strictly a ratio since the nominal rate is not in logarithms, but for our purposes it is simpler to call it a ratio.) Interest here again centres on whether these financial 'great ratios' are stationary over time.

Motivated by these concepts, the subsequent analysis in Sections III and IV considers whether empirical evidence can be found in support of stationarity for the four great ratios described above.

The data used to examine the statistical properties of the great ratios are quarterly time series observations for seven countries on output, consumption, investment, the money supply, prices and a short-term interest rate. The countries are those comprising the G7: Canada, France, Germany, Italy, Japan, the UK and the USA.

The national income account variables are all measured in per capita real terms and are seasonally adjusted. The data are analysed in logarithms. In deciding the precise measures to employ, the primary consideration is the treatment of government expenditures. King *et al.* (1991) do not include government spending in any of their measures, constructing a 'private' measure of output (gross national product less government expenditures) and making use of personal consumption and private investment series. Neusser (1991), in contrast, adds government consumption and investment to the respective private series, and consequently uses 'total' measures of the three national account variables. This latter approach is not directly possible for the USA since disaggregated government expenditure series are not available. Neusser overcomes this by adding federal government spending (excluding defence) to personal consumption, adding state and local government spending to private investment (as these expenditures have strong investment components), and defining output as gross national product minus national defence expenditures.

Of the two approaches we prefer the latter for the analysis in this paper, viewing government spending as a perfect substitute for private expenditures, following Neusser (1991). We therefore use real public plus private output, consumption and investment measures with the appropriate proxies employed for the USA. Each series is converted to per capita form using national population measures (International Financial Statistics series). Further, to provide a check with the King *et al.* (1991) approach, and to maintain congruity with their work, analysis for the USA is duplicated using the private measures of the variables and the population definition (total civilian noninstitutional population) used by these authors.

The money supply measure used is per capita M2 in logarithms (as in King *et al.*, 1991), although other measures are also considered for Italy and the UK because the available M2 series are relatively short for these countries. Prices are measured by the implicit price deflator of each country's output measure (in logarithms), and the short-term interest rate used is the three-month Treasury bill rate (Canada, France, Italy, UK, USA) or the interest rate on three-month foreign currency deposits in London (Germany, Japan).

In addition to duplicating the analysis for the King *et al.* private measures of US output, consumption and investment, analysis of the US real interest rate and real money supply growth is repeated using the King *et al.* measures of prices (the implicit price deflator of their private output variable) and population.

This study considers recent data, and to this extent, with a few exceptions, observations over the period 1972:1–1996:4 (100 observations) are used. To avoid the structural break of German reunification, the German series are truncated appropriately. In this regard, population figures include East Germany from 1987, so the series is ended at 1986:4 for most purposes. However, two exceptions are made to achieve longer time series where possible. First, the interest rate series is assumed not to undergo a structural break, and the full period to 1996:4 is used here. Secondly, in Section III the great ratios are constructed and examined using univariate techniques. Now the national account variables in non-per capita terms do not include East Germany until 1991, and in the construction of the

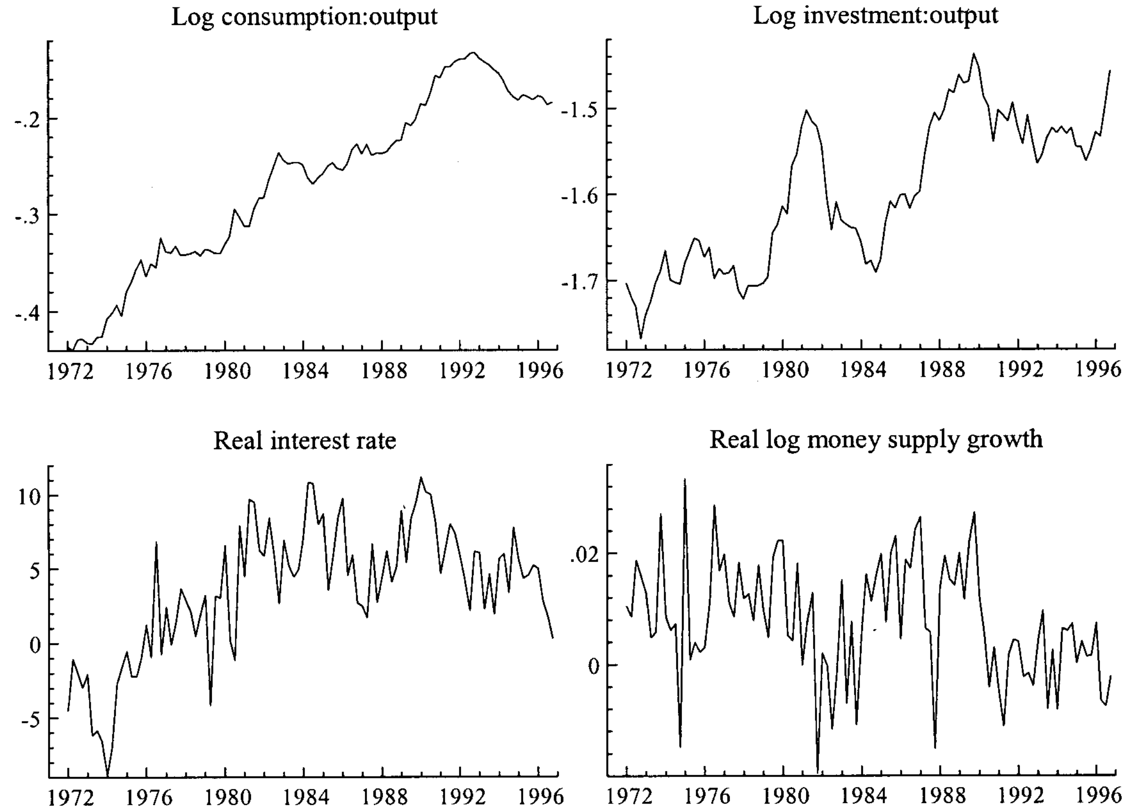

Fig. 1. *Canada great ratios*

ratios the population elements cancel. Thus in the univariate analysis the national account ratios can be extended to 1990:4 gaining sixteen observations.

The full details and precise definitions of the data for each country are given in the Appendix.

III. UNIVARIATE EMPIRICAL ANALYSIS

Unit root tests

The four great ratios considered can be constructed directly from the data and examined using univariate analysis. The ratios are log consumption:output $(c - y)$, log investment: output $(i - y)$, the real interest rate $(R - \Delta p)$[1] and real log money supply growth $(\Delta(m - p))$. Figures 1–8 show plots of all the ratios analysed for each country, providing an initial impression of the ratios' evolution over the period.

The most striking feature of these plots is that the great ratios of consumption:output and investment:output do not, at first glance, appear to be stationary. In many cases these ratios appear to drift through time, in other cases one is left with the impression of random walk behaviour. Turning to the financial ratios, the real money supply growth series are generally indicative of stationarity as might be expected, but the real interest rate plots are less clear.

These interesting first impressions are examined formally by unit root tests. First, augmented Dickey–Fuller (ADF) tests (Dickey and Fuller, 1979) are performed on the great ratios. A constant is included in the regression but trend terms are omitted since the possibility of trend stationary great ratios is not a sensible inference we wish to admit. The number of autoregressive lags included in the ADF regression is determined using a general-to-specific testing methodology, i.e. downward testing beginning with an arbitrarily large number of lags, in this case ten. Lag selection in this manner is performed in each case at the 5% and 10% significance levels. The results are given in Table 1.

The unit root test results confirm the impression gleaned from the time series plots. For the log consumption: output great ratio, we fail to reject the unit root null in practically every case. The only exception is the USA when a 10% level lag selection rule is used, and even then the null is only rejected at the 10% significance level. The overriding message from these simple tests is that there is next to no evidence for stationarity of the $c - y$ ratio.

[1] The nominal interest rate R is measured as an annual percentage, thus in the construction of the real interest rate, Δp is formulated as an annual percentage, i.e. $\Delta p = 400 \ln (P_t/P_{t-1})$.

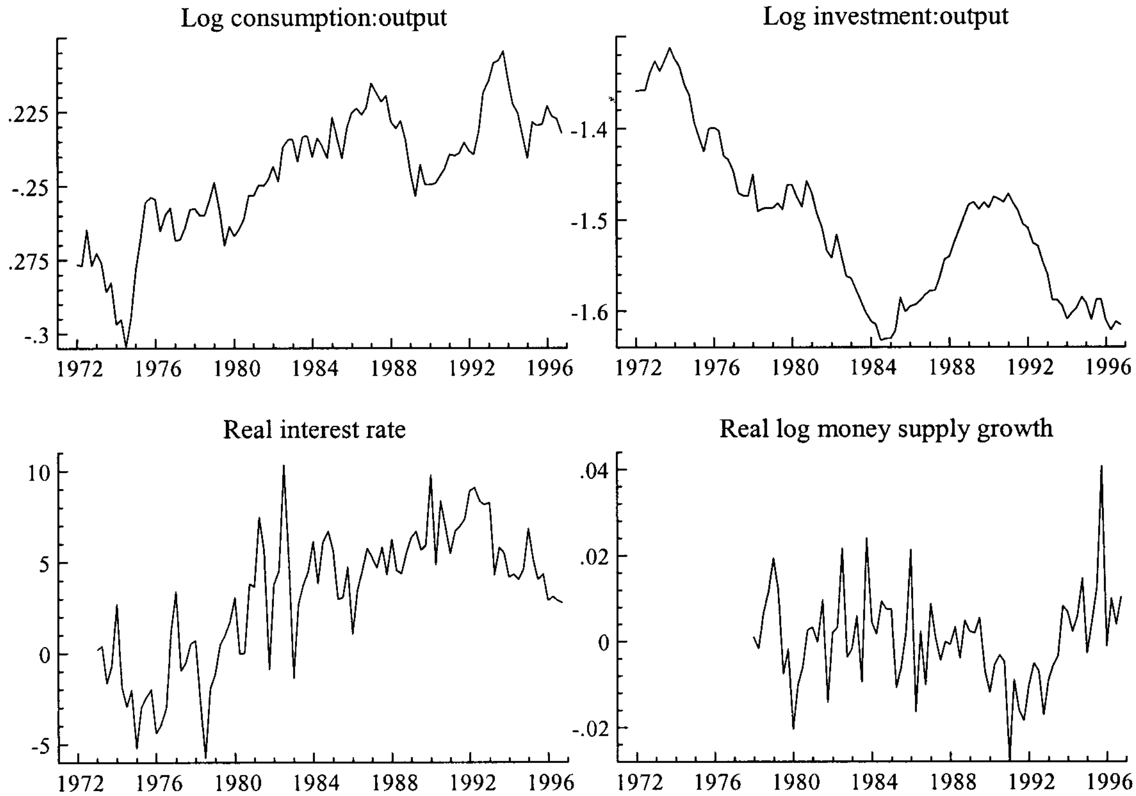

Fig. 2. *France great ratios*

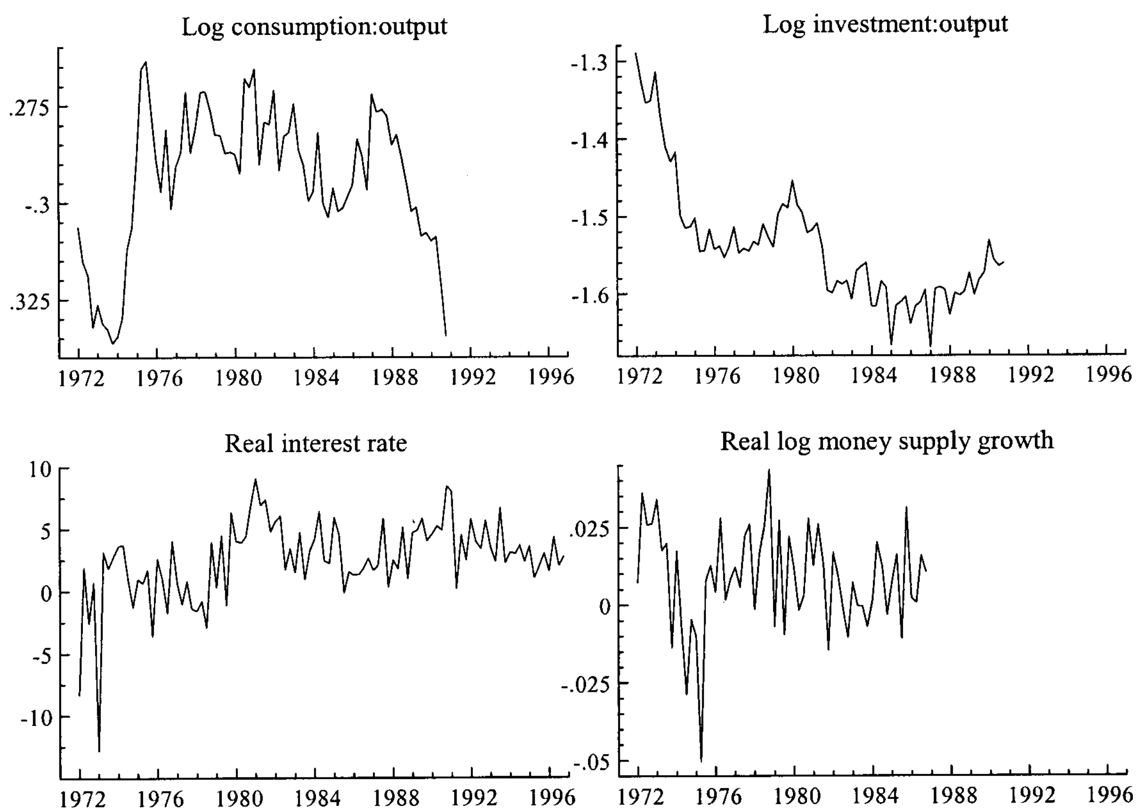

Fig. 3. *Germany great ratios*

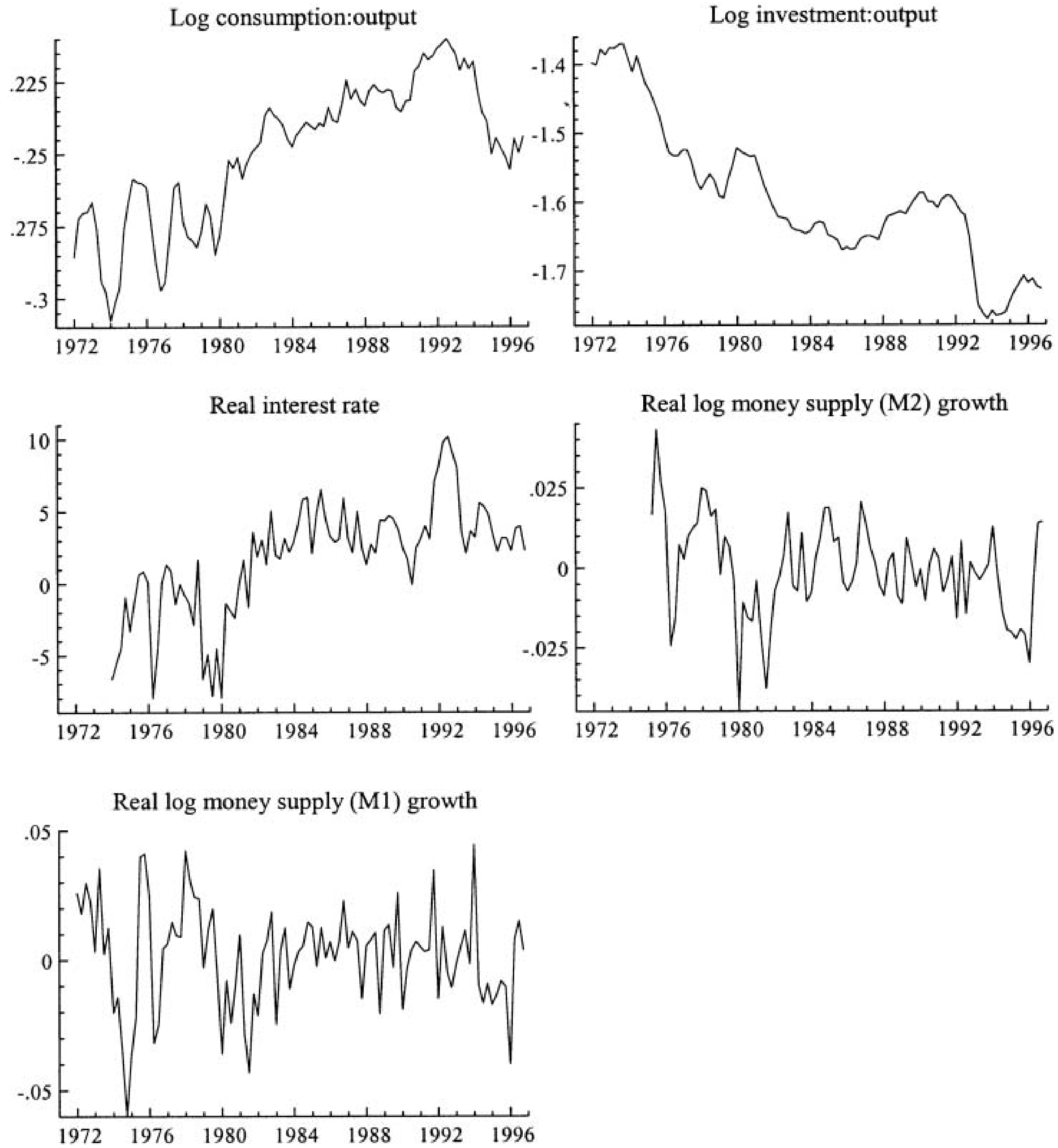

Fig. 4. *Italy great ratios*

The log investment:output ratio ADF tests lead to similar inferences, albeit to a slightly lesser degree. The strong rejection of the null for Germany is suspected to be spurious; visual inspection of the series indicates a process that is clearly nonstationary. A structural break appears to occur early on in the data, and this result is likely to be an example of the phenomenon observed by Leybourne *et al.* (1998a), where, if a break occurs early in a series, routine application of ADF tests can lead to serious spurious rejection of the unit root null. Dismissing this anomalous case, the only country for which rejections occur is the USA, particularly when the King *et al.* (1991) private measures are employed.

The real interest rate has mixed results across the G7 countries, with rejections in favour of stationarity for Germany, Italy and Japan, and no evidence against a unit root for Canada, France, the UK and the USA.

In contrast to the above, the real log money supply growth series are best characterized as stationary processes, with the exception of Canada. In most cases the null is rejected at the 5% or 1% level, providing strong evidence for stationarity.

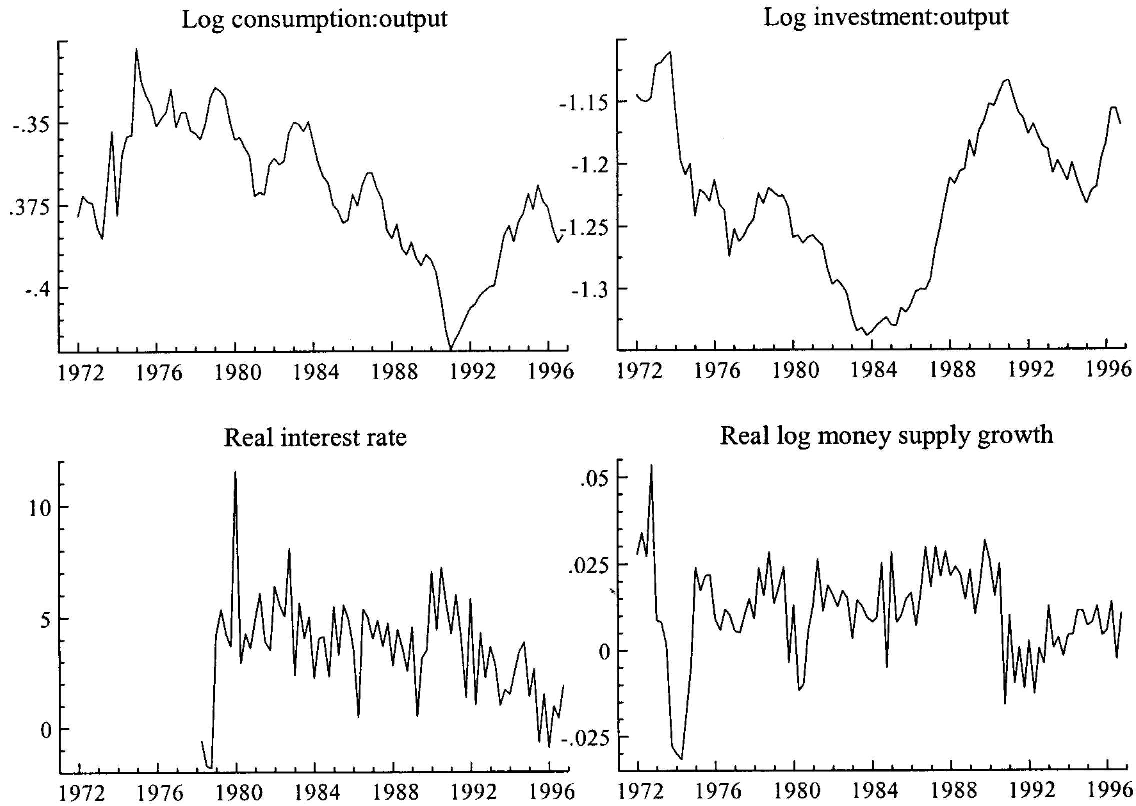

Fig. 5. *Japan great ratios*

Together, these initial unit root tests indicate that the only great ratio for which stationarity appears to hold internationally is real log money supply growth. The real interest rate is mixed, but perhaps the most noteworthy result is the broad lack of evidence for stationary behaviour in the log consumption:output and investment:output ratios. As regards the use of total versus private measures, comparison of the US results for both cases reveals general uniformity of inference. The only case where the results differ substantially is for the US $i - y$ ratio, and even then a rejection occurs with the total measures under a 10% level lag selection rule.

It is also worthwhile considering more general alternatives to the unit root null, other than stationarity about a fixed mean. To this end, the possibility is considered that the great ratios may be stationary about a structural break in the deterministic component (the mean). It is unrealistic to assume that such a break would occur instantaneously, thus the mean is allowed to change gradually and smoothly between two regimes. The technique employed is due to Leybourne *et al.* (1998b) and tests whether a series is integrated of order one, or $I(1)$, against the alternative of stationarity about a smooth transition in mean. The Leybourne–Newbold–Vougas test (LNV) follows an ADF-type procedure, being based on the residuals from a fitted (logistic) smooth transition regression. As with ADF-type tests, autoregressive lags of the residuals are included to account for any stationary dynamics, and the number of lags are chosen by downward testing as before. Specifically, let y_t denote a series of interest. The alternative to $I(1)$ behaviour is

$$y_t = \alpha_1 + \alpha_2 S_t(\gamma, \tau) + v_t$$

$$S_t(\gamma, \tau) = [1 + \exp\{-\gamma(t - \tau T)\}]^{-1}, \quad \gamma > 0 \qquad (4)$$

where T denotes series length. The error term v_t is stationary and modelled by a finite-order autoregression. This process models y_t as evolving from stationarity around mean α_1 to stationarity around mean $(\alpha_1 + \alpha_2)$. The parameter τ is the midpoint fraction of the transition, while γ determines the speed of transition, with a very large value for this parameter corresponding to virtually instantaneous transition. Details of a test of the $I(1)$ null hypothesis against this alternative are provided by Leybourne *et al.* (1998b). Broadening the scope of the alternative hypothesis in this way allows the possibility of discovering stronger support for the great ratios hypothesis, as the series mean is no longer constrained to be constant over the whole observation period. Tests are performed using this procedure for each ratio using both 5% and 10% significance level lag selection rules. Table 2 provides the results.

In interpreting the results, the concern is with cases where the ADF test unit root null could not be rejected.

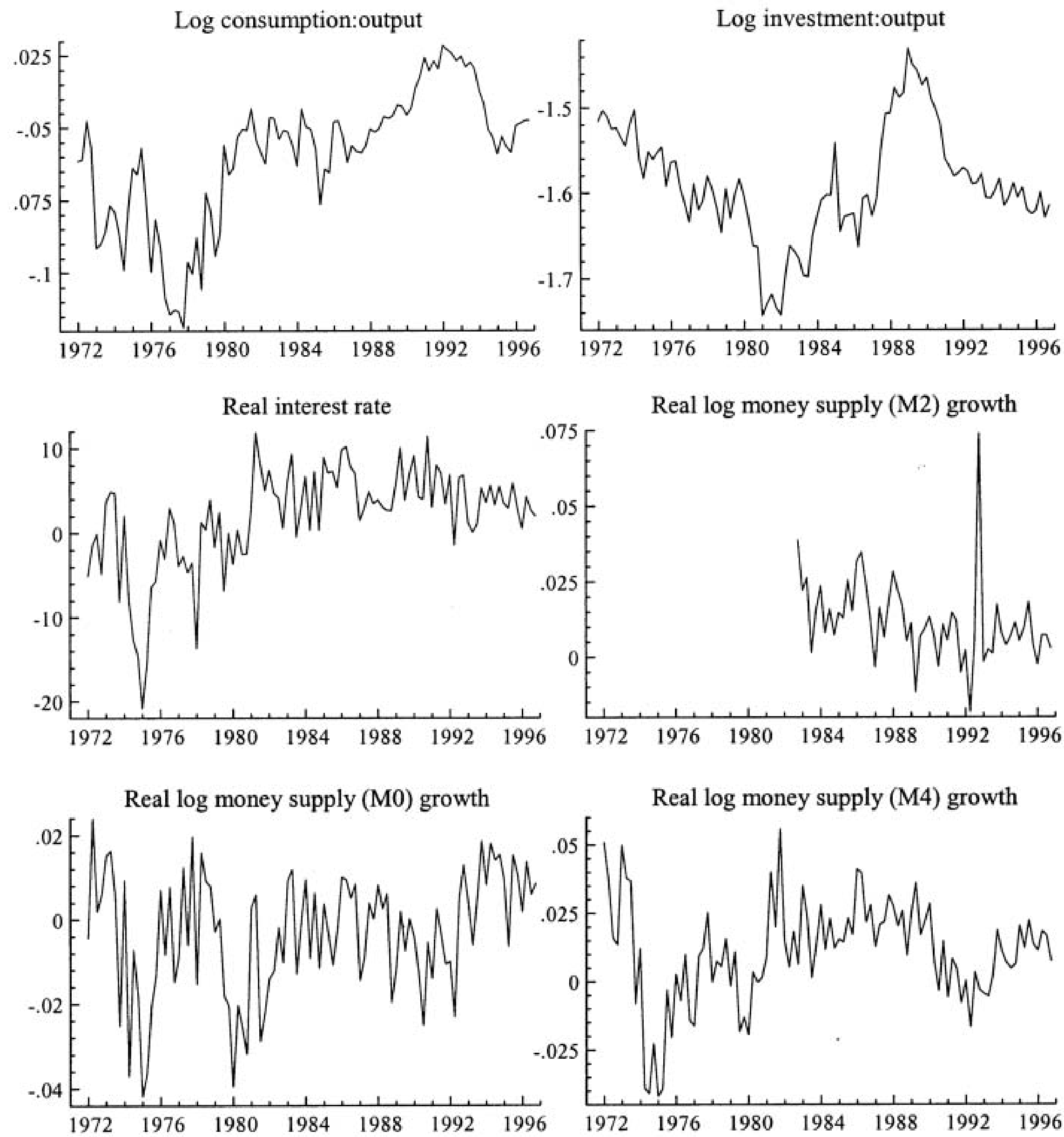

Fig. 6. *UK great ratios*

This follows from the fact that the LNV test does not contribute any valuable information when the ADF null is rejected.

First, the log consumption:output ratios exhibit a number of cases (France, Italy, UK, USA (King *et al.* measures)) where the ADF inference is a unit root process but application of the LNV test leads to a rejection. In such cases, the series are best described as stationary about a smooth transition in mean. This arguably provides some support for the balanced growth hypothesis in these countries, although the ratios are still strictly nonstationary due to the (smooth) break in mean. For the other countries' log consumption:output ratios, and also every log investment:output ratio, in each case where the ADF test fails to reject, a matching failure to reject occurs with the LNV test. Thus, use of the LNV test with its broader alternative hypothesis yields no further support for the stationarity of these ratios.

Taking the inferences from the ADF results and the LNV results together for the real interest rate, three series (Germany, Italy, Japan) appear to follow stationary processes, three are best characterized as unit root processes (France, both US ratios) and two (Canada, UK) are found to be stationary about a smooth transition in mean. This varied inference appears to be a feature of the real interest rate internationally, and an overall conclusion concerning this ratio's properties cannot be substantiated empirically. The only real money supply growth series of interest is

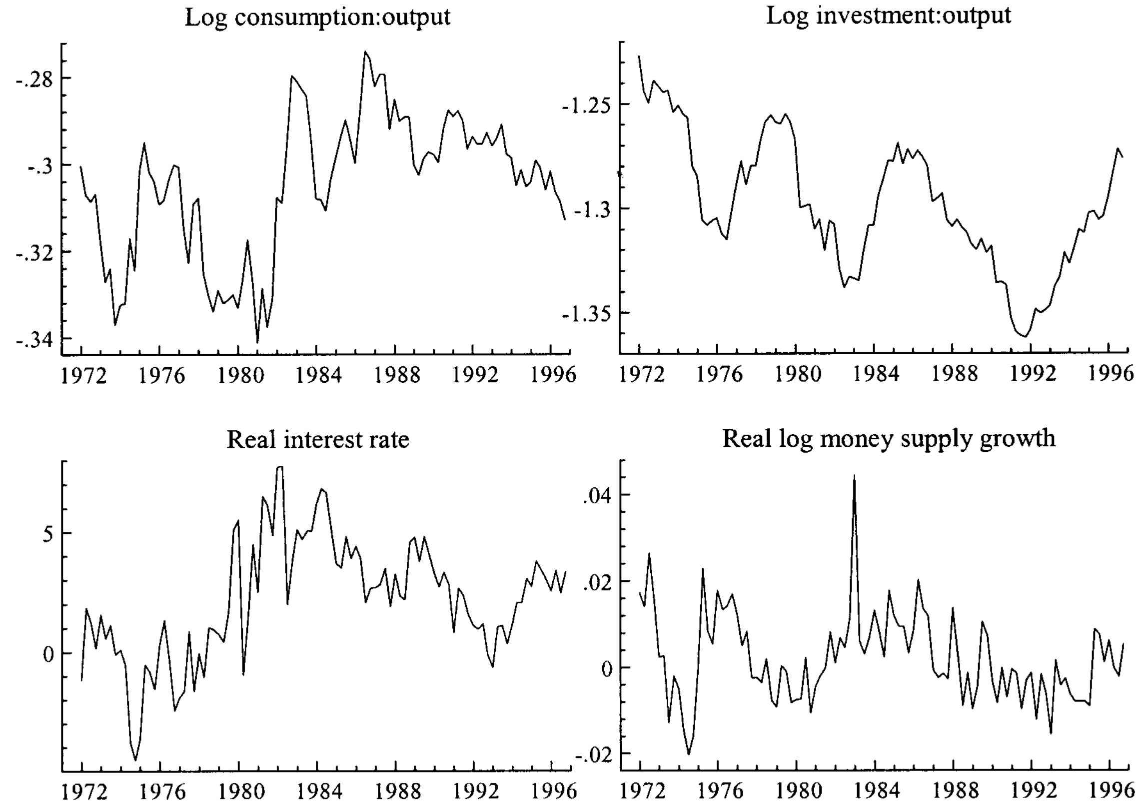

Fig. 7. *US great ratios*

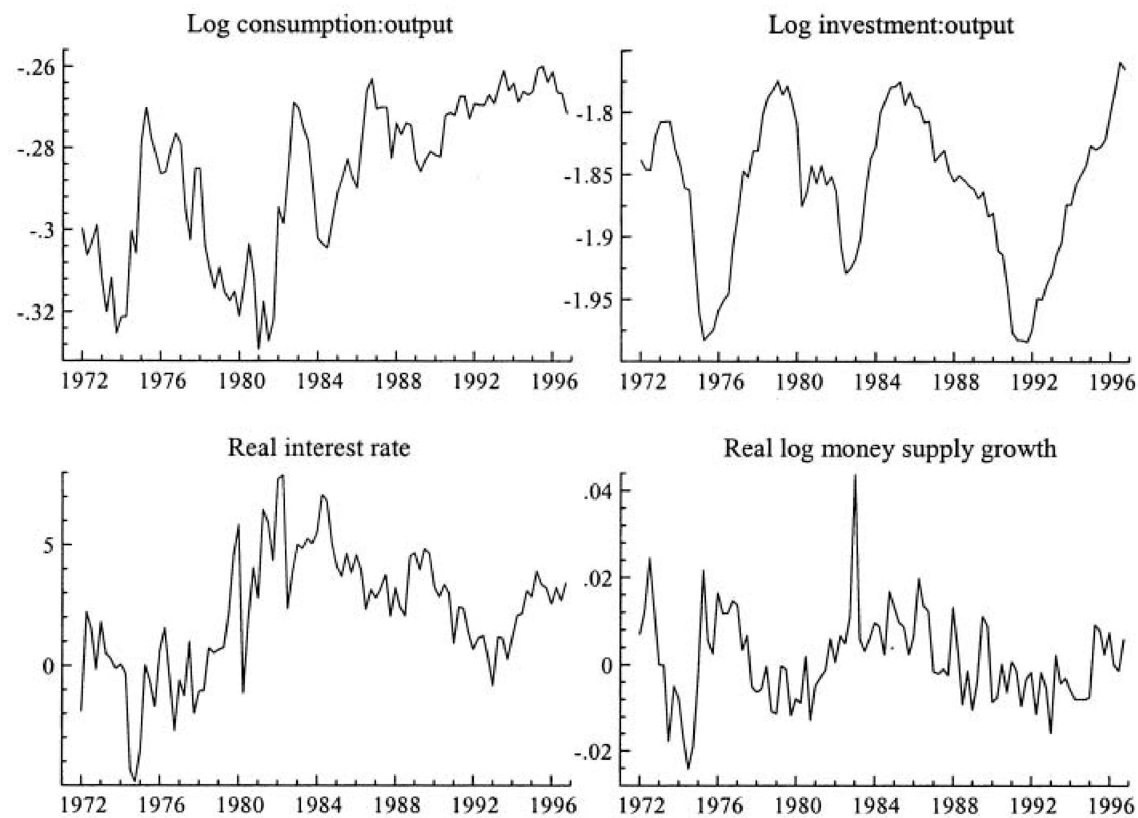

Fig. 8. *US great ratios (King* et al. *measures)*

Table 1. *Augmented Dickey–Fuller unit root tests*

Country	5% level lag selection		10% level lag selection	
	Number of lags	ADF statistic	Number of lags	ADF statistic
Log consumption:output ratio				
Canada	6	−2.147	6	−2.147
France	7	−1.895	7	−1.895
Germany	1	−2.013	1	−2.013
Italy	9	−2.158	9	−2.158
Japan	9	−1.171	9	−1.171
UK	1	−2.246	1	−2.246
USA	1	−2.353	4	−2.661*
USA (King *et al.* measures)	1	−2.132	1	−2.132
Log investment:output ratio				
Canada	1	−1.069	1	−1.069
France	1	−1.215	5	−2.218
Germany	5	−3.688***	5	−3.688***
Italy	2	−1.558	8	−2.077
Japan	8	−2.599	8	−2.599
UK	8	−2.470	8	−2.470
USA	1	−2.282	5	−2.856*
USA (King *et al.* measures)	10	−3.028**	10	−3.028**
Real interest rate				
Canada	2	−2.532	2	−2.532
France	5	−1.297	5	−1.297
Germany	4	−2.620*	4	−2.620*
Italy	2	−2.869*	2	−2.869*
Japan	2	−3.985***	2	−3.985***
UK	8	−1.778	8	−1.778
USA	3	−1.911	8	−1.485
USA (King *et al.* measures)	3	−1.882	8	−1.560
Real log money supply growth (M2 unless otherwise stated)				
Canada	5	−2.476	7	−2.451
France	2	−3.957***	2	−3.957***
Germany	7	−3.673***	7	−3.673***
Italy	1	−4.786***	9	−2.480
Italy (M1)	9	−3.065**	9	−3.065**
Japan	4	−5.772***	10	−2.563
UK	1	−6.772***	1	−6.772***
UK (M0)	9	−3.395**	9	−3.395**
UK (M4)	2	−3.535**	2	−3.535**
USA	1	−5.401***	1	−5.401***
USA (King *et al.* measures)	1	−5.387***	1	−5.387***

Note: * denotes significance at the 10% level, ** denotes significance at the 5% level and *** denotes significance at the 1% level.

Canada's (since ADF rejections occurred for every other country), and here the LNV test statistic is insignificant. Canada appears, therefore, to be an exception to the general discovery of international real money supply growth stationarity.

Stationarity tests

In the preceding subsection unit root tests were performed on the great ratios against two alternatives. However, given that we are concerned with examining evidence of ratio stationarity, it is desirable to test the *null* of stationarity, rather than merely infer its presence from the rejection of a unit root null. To this end, stationarity tests were also performed using a procedure proposed by Leybourne and McCabe (1994).

The test is based on the components model

$$\begin{aligned}\Phi(L)y_t &= \alpha + \alpha_t + \varepsilon_t \\ \alpha_t &= \alpha_{t-1} + \eta_t \end{aligned} \tag{5}$$

where $\varepsilon_t \sim \mathrm{IID}(0, \sigma_\varepsilon^2)$ and $\eta_t \sim \mathrm{IID}(0, \sigma_\eta^2)$. Here $\Phi(L) = 1 - \phi_1 L - \cdots - \phi_p L^p$ is a pth order autoregressive polynomial in the lag operator L, with roots outside the unit circle. Under the null hypothesis $\mathrm{H}_0: \sigma_\eta^2 = 0$, y_t is a stationary AR(p) process, and under the alternative

Table 2. *Leybourne–Newbold–Vougas unit root tests*

Country	5% level lag selection		10% level lag selection	
	Number of lags	LNV statistic	Number of lags	LNV statistic
Log consumption:output ratio				
Canada	6	−2.612	6	−2.612
France	4	−4.277**	4	−4.277**
Germany	1	−2.865	1	−2.865
Italy	2	−4.452**	9	−2.110
Japan	4	−3.381	4	−3.381
UK	1	−4.018*	1	−4.018*
USA	4	−3.270	4	−3.270
USA (King *et al.* measures)	4	−4.015*	4	−4.015*
Log investment:output ratio				
Canada	1	−2.241	10	−3.343
France	10	−3.271	10	−3.271
Germany	6	−3.683	6	−3.683
Italy	2	−2.474	2	−2.474
Japan	8	−1.837	8	−1.837
UK	8	−2.495	8	−2.495
USA	5	−2.839	6	−3.281
USA (King *et al.* measures)	10	−3.172	10	−3.172
Real interest rate				
Canada	1	−6.451***	1	−6.451***
France	6	−3.367	6	−3.367
Germany	4	−3.323	4	−3.323
Italy	1	−5.868***	5	−4.339**
Japan	2	−5.553***	5	−4.405**
UK	5	−5.349***	6	−5.878***
USA	3	−3.004	8	−2.154
USA (King *et al.* measures)	3	−3.008	8	−2.231
Real log money supply growth (M2 unless otherwise stated)				
Canada	5	−2.645	7	−2.165
France	2	−4.031*	2	−4.031*
Germany	7	−3.530	7	−3.530
Italy	1	−4.917***	9	−2.349
Italy (M1)	9	−3.039	9	−3.039
Japan	4	−6.055***	10	−3.260
UK	1	−7.697***	1	−7.697***
UK (M0)	9	−4.164*	9	−4.164*
UK (M4)	2	−4.120*	7	−4.526**
USA	1	−5.788***	8	−3.876
USA (King *et al.* measures)	1	−5.597***	8	−3.773

Note: * denotes significance at the 10% level, ** denotes significance at the 5% level and *** denotes significance at the 1% level.

$H_1: \sigma_\eta^2 > 0$, y_t can be shown to behave as a nonstationary ARIMA $(p, 1, 1)$ process. Leybourne and McCabe (1994) suggest the following statistic for testing H_0 against H_1:

$$S_p = s^2 T^{-2} e' V e \tag{6}$$

where T is the series length, $e = z - \bar{z}$ is the vector of deviations from means of the filtered variables

$$z_t = y_t - \sum_{i=1}^{p} \tilde{\phi}_i y_{t-i}$$

$s^2 = T^{-1} e' e$ and V is a $T \times T$ matrix with its ijth element equal to the minimum of i and j. The $\tilde{\phi}_i$ are estimates of the AR parameters when the ARIMA $(p, 1, 1)$ model $\Phi(L)\,\Delta y_t = (1 - \theta L) v_t$ is fitted to y_t using maximum likelihood methods. Leybourne and McCabe show that under the stationary null,

$$S_p \Rightarrow \int_0^1 B(r)^2 dr \tag{7}$$

where $B(r)$ is a demeaned Brownian motion process, and also that the test is consistent at the rate T under the nonstationary alternative. The order p of the autoregressive component is, of course, unknown in practice. Here, it is selected by joint use of information criteria and downward

Table 3. *Leybourne–McCabe stationarity tests*

Country	Order of autoregressive element	Leybourne–McCabe statistic
Log consumption:output ratio		
Canada	2	4.38***
France	4	3.54***
Germany	1	0.15
Italy	3	6.47***
Japan	3	5.80***
UK	1	4.74***
USA	4	0.88***
USA (King *et al.* measures)	4	1.64***
Log investment:output ratio		
Canada	1	5.58***
France	1	2.23***
Germany	4	1.38***
Italy	1	6.91***
Japan	1	1.24***
UK	0	1.03***
USA	1	0.96***
USA (King *et al.* measures)	1	0.30
Real interest rate		
Canada	0	4.22***
France	1	4.03***
Germany	4	0.09
Italy	2	0.99***
Japan	2	0.69**
UK	2	0.92***
USA	1	1.67***
USA (King *et al.* measures)	3	0.10
Real log money supply growth (M2 unless otherwise stated)		
Canada	5	0.21
France	0	0.29
Germany	3	0.07
Italy	1	0.11
Italy (M1)	1	0.03
Japan	5	0.48**
UK	0	0.68**
UK (M0)	2	0.33
UK (M4)	2	0.12
USA	1	0.15
USA (King *et al.* measures)	1	0.09

Note: * denotes significance at the 10% level, ** denotes significance at the 5% level and *** denotes significance at the 1% level.

testing using the t-ratios of the estimated AR parameters in the fitted ARIMA model. In downward testing an ARIMA $(8, 1, 1)$ model is taken as the most general specification and a sequence of two-tailed tests at the 10 per cent level is performed using critical values from the normal distribution. The results can be seen in Table 3.

The Leybourne–McCabe tests generally provide inference consistent with that derived from the unit root tests. Stationarity of the log consumption:output and log investment:output ratios is rejected at the 1% level in all but two cases. These rejections are parallelled by inferences of nonstationarity (either unit root or stationary about a structural break) in the previous subsection; together these tests generate strong evidence against the balanced growth hypothesis. The two cases where the Leybourne–McCabe test does not reject the stationarity null are German consumption:output and USA (King *et al.* measures) investment:output. The former conflicts with the ADF and LNV inferences of ratio nonstationarity and it is consequently unclear how to best describe this series. The latter, however, is consistent with the ADF results and comprises an exception to the general conclusion concerning this ratio's properties internationally.

The real interest rate results are mixed as before, and in three cases conflict with the unit root test conclusions. If anything, these results indicate less support for real interest rate stationarity across the countries considered. Application of the Leybourne–McCabe test to the real money supply growth series again leads to a broad conclusion of ratio stationarity. Canada no longer appears to be an exception, although the null is now rejected for Japan and the UK M2 series (the latter of which is a short and therefore somewhat unreliable time series).

IV. MULTIVARIATE EMPIRICAL ANALYSIS

The notion of great ratio stationarity can also be described in terms of cointegration, as defined by Engle and Granger (1987). In our framework, if the logarithms of output, consumption and investment are nonstationary, and more specifically $I(1)$, then for the great ratios $c - y$ and $i - y$ to be stationary, log consumption and log investment must respectively be cointegrated with log output. Further, the cointegrating parameter in each case must be one, i.e. cointegration implies that, for example, $c - \lambda y$ is stationary; we require $\lambda = 1$ for great ratio stationarity.

To analyse evidence for such hypotheses a trivariate vector autoregression (VAR) is constructed for each country and the presence and properties of cointegrating relations between the three variables (log output, log consumption, log investment) is investigated. Because the variables are trended, both intercept and trend terms are included in the VAR, although the trend is restricted to lie in the cointegrating space to prevent the possibility arising of a quadratic deterministic trend in levels.

Before cointegration analysis can commence, the order of the VAR must be determined for each country. The basic procedure for order selection follows a general-to-specific downward testing strategy, beginning with an order of eight. (Lags which date back before 1972:1 use data prior to the normal set of observations.) Downward testing is performed using a likelihood ratio test for significance of the highest lag parameters, as outlined by, for example, Lütkepohl (1993). Sims (1980) proposes a

Table 4. *Johansen order of cointegration tests*

Country	VAR order	Statistic	$H_0: r = 0$	$H_0: r \leqslant 1$	$H_0: r \leqslant 2$
Canada	6	Trace	55.25***	29.17**	9.14
		Adjusted trace	45.31**	23.92*	7.49
		Maximal-eigenvalue	26.08**	20.03**	9.14
		Adjusted max.-eigenvalue	21.39	16.42	7.49
France	4	Trace	33.83	15.75	3.83
		Adjusted trace	29.77	13.86	3.37
		Maximal-eigenvalue	18.08	11.92	3.83
		Adjusted max.-eigenvalue	15.91	10.49	3.37
Germany	6	Trace	55.12***	27.90**	10.17
		Adjusted trace	38.58	19.53	7.12
		Maximal-eigenvalue	27.22**	17.73*	10.17
		Adjusted max.-eigenvalue	19.05	12.41	7.12
Italy	5	Trace	45.28**	16.44	6.41
		Adjusted trace	38.49	13.97	5.45
		Maximal-eigenvalue	28.84**	10.03	6.41
		Adjusted max.-eigenvalue	24.52*	8.52	5.45
Japan	8	Trace	46.21**	22.35	6.25
		Adjusted trace	35.12	16.99	4.75
		Maximal-eigenvalue	23.86*	16.11	6.25
		Adjusted max.-eigenvalue	18.14	12.24	4.75
UK	7	Trace	46.05**	20.74	5.94
		Adjusted trace	36.38	16.38	4.69
		Maximal-eigenvalue	25.31*	14.80	5.94
		Adjusted max.-eigenvalue	20.00	11.69	4.69
USA	6	Trace	71.31***	30.96***	2.72
		Adjusted trace	58.48***	25.39**	2.32
		Maximal-eigenvalue	40.35***	28.24***	2.72
		Adjusted max.-eigenvalue	33.09***	23.16**	2.32
USA (King *et al.* measures)	6	Trace	56.52***	15.54	2.66
		Adjusted trace	46.34**	12.74	2.18
		Maximal-eigenvalue	40.98***	12.88	2.66
		Adjusted max.-eigenvalue	33.60***	10.56	2.18

Note: * denotes significance at the 10% level, ** denotes significance at the 5% level and *** denotes significance at the 1% level.

finite sample adjustment to this test. Both variants of the test are employed, with selections made at the 5% and 10% levels. Where these decision rules lead to conflicting outcomes, the choice of order is made on the bases of parsimony and minimizing residual autocorrelation. The VAR orders for the G7 countries are listed in Table 4.

Given the order of the VAR, we proceed to test for the presence of cointegration, assuming that the variables are $I(1)$. The methodology employed is due to Johansen (1988) who provides an integrated maximum likelihood approach to estimation and testing. First, the order of cointegration is found by sequentially performing Johansen's test of the null of at most r cointegrating vectors against the alternative of more than r cointegrating vectors, for $r = 0, 1, 2$. The trace and maximal-eigenvalue statistics associated with these tests are given in Table 4. 'Adjusted' statistics are also reported which embody a small-sample modification recommended by Reimers (1992). Critical values for the tests are provided by Osterwald-Lenum (1992). From these results, the order of cointegration, i.e. the number of cointegrating relations, can be deduced.

For all countries except France, some degree of cointegration is detected by the Johansen tests. To be in support of the balanced growth hypothesis one would expect to find evidence of two cointegrating relations. Favouring an inference of a higher order of cointegration where possible, it can be concluded that there are two cointegrating relations for Canada and the USA (total measures), one or two for Germany, one (at most) for Italy, Japan, the UK and the USA (King *et al.* measures), and none for France. This initial stage therefore gives varied support for balanced growth.

Imposing the order of cointegration allows one to estimate the cointegrating vector(s); results of this estimation can be seen in Table 5. In each case the highest value of r that can be substantiated by the tests is used (for Germany, values of both $r = 1$ and $r = 2$ are utilized since a clear inference between these orders is difficult). The cointegrating vectors β_i, $i = 1, \ldots, r$ are estimated using the Johansen (1988) technique, and each vector is normalized on log consumption and log investment separately.

Table 5. *Cointegrating vector estimation and Johansen cointegrating vector restriction tests*

Country	r	$\hat{\beta}_1$ normalized on c, i respectively				$\hat{\beta}_2$ normalized on c, i respectively				LR test: c-y	LR test: i-y	LR test: c-y, i-y
Canada	2	c	1.000	c	1.476	c	1.000	c	−1.964	8.13**	10.95***	17.79***
		i	0.677	i	1.000	i	−0.059	i	1.000			
		y	−2.024	y	−2.988	y	−0.847	y	1.665			
		t	−0.003	t	−0.005	t	0.001	t	−0.002			
France	0											
Germany	1	c	1.000	c	3.780					13.20***	18.62***	
		i	0.265	i	1.000							
		y	−1.301	y	−4.917							
		t	0.001	t	0.005							
	2	c	1.000	c	3.780	c	1.000	c	3.714	8.45**	9.16**	24.23***
		i	0.265	i	1.000	i	0.269	i	1.000			
		y	−1.301	y	−4.917	y	−2.430	y	−9.109			
		t	0.001	t	0.005	t	0.007	t	0.025			
Italy	1	c	1.000	c	−3.478					20.70***	16.57***	
		i	−0.288	i	1.000							
		y	−1.856	y	6.456							
		t	0.005	t	−0.019							
Japan	1	c	1.000	c	154.520					16.64***	18.60***	
		i	0.006	i	1.000							
		y	−0.518	y	−80.051							
		t	−0.002	t	−0.382							
UK	1	c	1.000	c	−4.017					18.48***	15.72***	
		i	−0.249	i	1.000							
		y	−0.059	y	0.237							
		t	−0.004	t	0.014							
USA	2	c	1.000	c	2.319	c	1.000	c	22.081	22.74***	16.32***	30.82***
		i	0.431	i	1.000	i	0.045	i	1.000			
		y	−1.068	y	−2.476	y	−1.514	y	−33.422			
		t	−0.002	t	−0.004	t	0.001	t	0.036			
USA (King *et al.* measures)	1	c	1.000	c	−11.994					36.06***	23.23***	
		i	−0.083	i	1.000							
		y	−2.103	y	25.225							
		t	0.004	t	−0.044							

Note: * denotes significance at the 10% level, ** denotes significance at the 5% level and *** denotes significance at the 1% level.

The crux of this multivariate analysis can now be undertaken to determine whether the data support cointegrating relations which define the great ratios. It is possible to test the great ratio restrictions $c - y$ (i.e. $\beta_1 = [1 \quad 0 \quad -1 \quad 0]'$) and $i - y$ (i.e. $\beta_1 = [0 \quad 1 \quad -1 \quad 0]'$) separately using Johansen likelihood ratio tests (see Johansen, 1995 for a full exposition). The last element in each vector corresponds to restricting the trend element in the cointegrating relation to zero, as required for great ratio stationarity. In the cases where two cointegrating relations are imposed, we further test the joint restriction $c - y$, $i - y$ (i.e. $\beta_1 = [1 \quad 0 \quad -1 \quad 0]'$, $\beta_2 = [0 \quad 1 \quad -1 \quad 0]'$). As can be seen from the results in Table 5 these restrictions are very strongly rejected (at least at the 5% level) in every case. The data therefore provide no substantive support for cointegration with great ratio restrictions (although some less restrictive form of cointegration is found to be present in most countries). These multivariate results are consequently not consistent with the balanced growth theory for the G7 countries, matching the conclusions of the univariate analysis for the log consumption:output and log investment:output ratios.

V. CONCLUSION

In this paper the implications of balanced growth and stochastic growth theories have been tested empirically, using recent data for the G7 countries. The consistent message from the results is that the log consumption: output and log investment:output great ratios are not, in general, stationary. The findings are thus not favourable to the balanced growth/neoclassical stochastic growth hypotheses. Also considered are the financial ratios of real log money supply growth and the real interest rate. Strong evidence is found for real money supply growth stationarity across the countries considered. Inference concerning the real interest rate is less conclusive, with some series displaying stationary behaviour, others not.

The measures of the national income account variables used include government expenditures, and a check against use of the alternative private measures is made for the USA. The difference in measures does not appear to have an appreciable effect, with perhaps the exception of the US investment:output ratio in some cases.

Together the results provide international evidence in favour of growth and real business cycle models that do not assume exogenous and permanent stochastic productivity shocks, which lead to the common trend hypothesis. Further, it does not appear to be wise to put too much faith in an assumption of real interest rate stationarity without prior testing for a particular country.

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APPENDIX: DATA DESCRIPTION

Canada			
Income	Per capita gross domestic product	1992 Canadian dollars	1972:1–1996:4
Consumption	Per capita public plus private consumption	1992 Canadian dollars	1972:1–1996:4
Investment	Per capita gross public plus private fixed investment	1992 Canadian dollars	1972:1–1996:4
Prices	Implicit price deflator of gross domestic product	Index: 1992 = 100	1972:1–1996:4
Interest rate	Three-month Treasury bill rate	Annual percentage	1972:1–1996:4
Money supply	Per capita money supply M2	Canadian dollars	1972:1–1996:4
France			
Income	Per capita gross domestic product	1980 French francs	1972:1–1996:4
Consumption	Per capita public plus private consumption	1980 French francs	1972:1–1996:4
Investment	Per capita gross public plus private fixed investment	1980 French francs	1972:1–1996:4
Prices	Implicit price deflator of gross domestic product	Index: 1980 = 100	1972:1–1996:4
Interest rate	Three-month Treasury bill discount rate	Annual percentage	1973:1–1996:4
Money supply	Per capita money supply M2	French francs	1978:1–1996:4
Germany			
Income	Per capita gross domestic product	1991 deutschmarks	1972:1–1990:4
Consumption	Per capita public plus private consumption	1991 deutschmarks	1972:1–1990:4
Investment	Per capita gross public plus private fixed investment	1991 deutschmarks	1972:1–1990:4
Prices	Implicit price deflator of gross domestic product	Index: 1991 = 100	1972:1–1996:4
Interest rate	Interest rate on 3-month DM deposits in London	Annual percentage	1972:1–1996:4
Money supply	Per capita money supply M2	Deutschmarks	1972:1–1986:4
Italy			
Income	Per capita gross domestic product	1990 lira	1972:1–1996:4
Consumption	Per capita public plus private consumption	1990 lira	1972:1–1996:4
Investment	Per capita gross public plus private fixed investment	1990 lira	1972:1–1996:4
Prices	Implicit price deflator of gross domestic product	Index: 1990 = 100	1972:1–1996:4
Interest rate	Three-month Treasury bill rate	Annual percentage	1974:1–1996:4
Money supply	Per capita money supply M2	Italian lira	1975:2–1996:4
	Per capita money supply M1	Italian lira	1972:1–1996:4
Japan			
Income	Per capita gross domestic product	1990 yen	1972:1–1996:4
Consumption	Per capita public plus private consumption	1990 yen	1972:1–1996:4
Investment	Per capita gross public plus private fixed investment	1990 yen	1972:1–1996:4
Prices	Implicit price deflator of gross domestic product	Index: 1990 = 100	1972:1–1996:4
Interest rate	Interest rate on 3-month yen deposits in London	Annual percentage	1978:2–1996:4
Money supply	Per capita money supply M2	Yen	1972:1–1996:4
United Kingdom			
Income	Per capita gross domestic product	1990 pounds	1972:1–1996:4
Consumption	Per capita public plus private consumption	1990 pounds	1972:1–1996:4
Investment	Per capita gross public plus private fixed investment	1990 pounds	1972:1–1996:4
Prices	Implicit price deflator of gross domestic product	Index: 1990 = 100	1972:1–1996:4
Interest rate	Three-month Treasury bill rate	Annual percentage	1972:1–1996:4
Money supply	Per capita money supply M2	Pounds	1982:4–1996:4
	Per capita money supply M0	Pounds	1972:1–1996:4
	Per capita money supply M4	Pounds	1972:1–1996:4
United States			
Income	Per capita gross domestic product (excluding defence)	1992 US dollars	1972:1–1996:4
Consumption	Per capita private consumption plus federal government spending (excluding defence)	1992 US dollars	1972:1–1996:4
Investment	Per capita gross private fixed investment plus state and local government spending	1992 US dollars	1972:1–1996:4
Prices	Implicit price deflator of gross domestic product measure	Index: 1992 = 100	1972:1–1996:4
Interest rate	Three-month Treasury bill rate	Annual percentage	1972:1–1996:4
Money supply	Per capita money supply M2	US dollars	1972:1–1996:4
United States (King *et al.* measures)			
Income	Per capita* gross national product minus government spending	1992 US dollars	1972:1–1996:4
Consumption	Per capita* private consumption	1992 US dollars	1972:1–1996:4
Investment	Per capita* gross private fixed investment	1992 US dollars	1972:1–1996:4
Prices	Implicit price deflator of gross national product measure	Index: 1992 = 100	1972:1–1996:4
Interest rate	Three-month Treasury bill rate	Annual percentage	1972:1–1996:4
Money supply	Per capita* money supply M2	US dollars	1972:1–1996:4

* using total civilian noninstitutional population
Source: Datastream.