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Testing for unit roots and persistence in OECD unemployment rates

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The natural rate hypothesis in economics is represented as a trend-stationary (TS) process while the hysteresis hypotheses in economics are represented as difference-stationary (DS) processes. Persistence, a notion often confused with hysteresis, is shown to be long-memory TS process. The presence of persistence means that shocks to unemployment rates have long durations. While formally TS processes, highly persistent (near unit root) processes, in practice provide aggregate demand policy with scope to attentuate the effects of a shock before subsequent shocks occur. Extreme natural rate conceptions do not permit such policy effectiveness. Unit root tests aimed at distinguishing between TS and DS hypotheses are conducted. In most of the OECD countries examined, the null of the unit root (DS) is not rejected. An examination is made of the Perron argument, that the widespread acceptance of the unit root hypothesis within recent literature arises because of mis-specification in the testing regression, specifically the failure to account for segmented trends. This contention is not found to be crucial in our study which confirms the widespread acceptability of the unit root hypothesis in OECD unemployment rates even after accounting for possible breaks in the trend function. Recognising the low power of the unit root tests against near unit root alternatives, the paper also derives and calculates the degree of persistence in OECD unemployment rates, to assess whether there is scope for policy initiatives aimed at permanently lowering the unemployment rate. It is concluded that the rates exhibit large degrees of persistence which allows scope for policy intervention.

I. INTRODUCTION

There are two main alternative hypotheses about the relationship between the business cycle and the steady state in macroeconomics: the natural rate hypothesis (NRH) and the hysteresis hypothesis (HH). Each presents a distinct prescription for the design and conduct of aggregate economic policy.

The NRH, a central pillar of orthodox, market-clearing theory, distinguishes between the long-term secular trend and the short-term (transitory) fluctuations in the economy. At best, aggregate demand management can only stabilize the short-term variations, but in the NRH it is usually considered to inhibit the 'natural' tendencies of an economy (if shocked) to equilibrate, and ultimately only influences nominal magnitudes (that is, causes inflation).

The HH relates to path-dependence in dynamic systems (Cross, 1986; Mitchell, 1987; Franz, 1990; Watts and Mitchell, 1991). Franz (1990, p. 2) says that 'The long-run solution of such a system does not only depend on the long-run values of the exogenous variables (as usually) . . . [that is, under NRH models] . . . but also on the initial condition of each state variable.' Buiter (1987, p. 24) expresses path-dependence as, 'Where you get to is determined by how you get there.' Accordingly, expansionary policy can permanently reduce unemployment at the cost of

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some inflation. The price level acceleration is finite as the economy adjusts to a new lower steady-state unemployment rate.[1]

While the distinction between these hypotheses is clear in theory, on a practical basis the divide is somewhat blurred. The concept of unemployment persistence is important in this regard. In analytical terms, persistence is a special case of the NRH. An economy with strong persistence takes many periods to adjust back to equilibrium following a shock. So even if the NRH is a true model of the economy, persistence means that the effects of shocks have long memories and that short-term macroeconomic policy can be effective.

A further consideration is the apparent tension between the theoretical and the empirical literature on unit roots and hysteresis. Much of the theoretical work on hysteresis uses a path-dependent steady-state unemployment rate as a model of hysteresis (Blanchard and Summers, 1986, 1987; Franz, 1990). Nelson and Plosser (1982) found that the unemployment rate was the only time-series to reject the unit-root hypothesis (see also Evans, 1989). Perron (1989, p. 1363) did not 'analyze the unemployment rate series since there is a general agreement that it is stationary'. Perron (1988, p. 321) confirmed this belief and concluded for the United States that 'the unemployment rate series. . . [is] . . . stationary around a linear trend (albeit a zero trend. . .).' The problem is simple. Either the theoretical possibility of hysteresis in the unemployment rate is erroneous or there is a need for more comprehensive unit-root testing.[2]

Section II relates the distinction made by Nelson and Plosser (1982) between trend-stationary and difference-stationary processes to the NRH and the HH. The concept of persistence is shown to be a special case of the NRH. Interestingly, on a practical basis, this special case has the same policy implications as hysteresis. Section III provides historical evidence to motivate our analysis. Despite remaining at low average rates for many years, the aggregate unemployment rates for Australia and the United States of America (USA) generate test statistics which do not reject the unit-root hypothesis. At the very least, the unemployment rates of these countries exhibit strong persistence. It appears that we cannot simply dismiss the post-1960s period as being a case of a mean shift. Section IV presents some additional evidence on the degree of persistence in the OECD unemployment rates as a precursor to more formal testing. The measures clearly show that when shocked, the output gaps for all the OECD countries examined remain significant for many years. Section V outlines the unit-root testing framework. Section VI presents and analyses the results of the formal unit root tests. Section VII examines the segmented trend approach and the modified test results based on this hypothesis. Concluding remarks follow.

II. DIFFERENCE-STATIONARY AND TREND-STATIONARY PROCESSES

Nelson and Plosser (1982) compare trend-stationary (TS) to difference-stationary (DS) processes. They say that macroeconomics commonly separates a non-stationary 'secular or growth component' from a stationary 'cyclical component' when decomposing real (and sometimes nominal) economic time-series. The transitory disturbances are due to monetary shocks. This representation is termed a TS process. Alternatively, integrated (DS) processes exhibit non-stationarity which is stochastic and displays no automatic tendency to return to any deterministic trend. DS processes cannot provide long-term forecasts based on the mean of the series. Whereas the past history of the TS process does not influence its long-term value, the magnitude of a variable following a DS process is the sum of its past.

The linear model which nests both hypotheses (as alternatives) is

$$y_t = \gamma + \beta t + u_t/(1 - \alpha L) \quad (1)$$

where L is the lag operator. Under the null of a unit root, $\alpha = 1$, the implied value of β is zero. The unit-root hypothesis becomes the joint hypothesis $(\beta, \alpha) = (0, 1)$ (see Nelson and Plosser, 1982, p. 144).

The NRH and the HH can be represented as TS and DS processes, respectively. Franz (1990) says that in the context of 'discrete time linear systems hysteresis is present when there are one or more unit roots in the characteristic equation of the state matrix'. (see also Watts and Mitchell, 1991). The representation of hysteresis can take a number of forms. As an example, Franz (1990, Section 2) models the unemployment rate as a simple autoregressive process

$$u_t = du_{t-1} - Z_t \quad (2)$$

[1] A variety of empirical approaches have attempted to detect hysteresis in various countries. Hargreaves–Heap (1980), Mitchell (1987), Coe and Gagliardi (1985), Coe (1988) and Watts and Mitchell (1990) employed a Phillips curve framework with alternative specifications of the steady-state unemployment rate nested. Each study found some evidence of hysteresis. Möller (1990) explores human capital deterioration as a source of hysteresis. He uses a Beveridge curve framework to test whether in times of high unemployment the steady-state unemployment–vacancy relation bows out from the usual relation. Franz (1990) discusses other techniques which have been used.

[2] We should be careful though. As Brunello (1990) observes, 'since the unemployment rate is a bounded variable, it cannot in principle follow a pure unit-root process.' However, the detection of a unit root over an extended sample, say the post-war period, has significant implications for the conduct of economic policy, even though, over an infinite sample, the variance of the process may operate within finite bounds.

where Z is an exogenous (aggregate demand) variable and d is a parameter. Solving the steady-state value of u_t gives

$$\bar{u} = \bar{Z}/(1-d) \tag{3}$$

which means that the equilibrium of $\bar{u}$ is a function solely of the equilibrium value of $\bar{Z}$ if d differs from unity. There is no path dependence in the equilibrium unemployment rate.

A non-unique, path-dependent equilibrium emerges if $d=1$. In this case, the current value of $\bar{u}$ is a function of the starting value of u and the accumulation of period values of Z. With $d=1$ in Equation 2 and accumulating u_t from some starting value u_0, we get

$$u_t = u_0 + \sum Z_t \tag{4}$$

Relating these insights to the TS–DS distinction from Nelson and Plosser (1982) is straightforward. We have equated the presence of a unit root in a time series as being equivalent to hysteresis. An integrated stochastic process (u_t), like a random walk with fixed drift, is a DS process and is written as

$$u_t = u_{t-1} + \beta + \varepsilon_t \tag{5}$$

and can be re-expressed along the lines of Equation 4 as an accumulation process such that

$$u_t = u_0 + \beta t + \sum \varepsilon_t \tag{6}$$

A TS model in linear terms can be defined as a stochastic process which follows a secular trend such as

$$u_t = \alpha + \beta t + \varepsilon_t \tag{7}$$

where t is a linear time trend and ε_t is a stationary series with zero mean and variance σ^2. Once we eliminate the secular component of the series, $(\alpha + \beta t)$, the residuals sum to zero and are stationary ($\Sigma t\varepsilon_t = 0$).

While Equation 6 exhibits a linear trend as in Equation 7, the error term is not stationary and the variance ($t\sigma^2$) increases with time. The DS process thus requires differencing before the residuals are stationary. This is the basis of the TS/DS distinction.

In terms of Equation 1, if α was a near unit root (say 0.95), then the resulting TS process would exhibit substantial persistence. An innovation to this type of model would not have permanent effects, but the process would still have a long memory. Thus persistence is a special case of the NRH. Although persistence is clearly distinct from hysteresis in analytical terms, it is virtually equivalent in practical terms because a long memory process provides room for policy effectiveness.

III. A HISTORICAL PERSPECTIVE

Figures 1 and 2 plot unemployment rate in Australia (1861–1984), and the USA (1890–1984), respectively. In each case the plots demonstrate highly autoregressive behaviour,

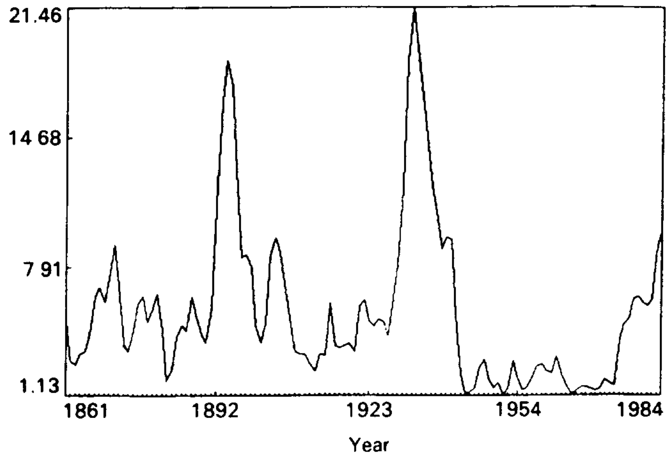

Fig. 1. *Aggregate unemployment rate, Australia 1861–1984*

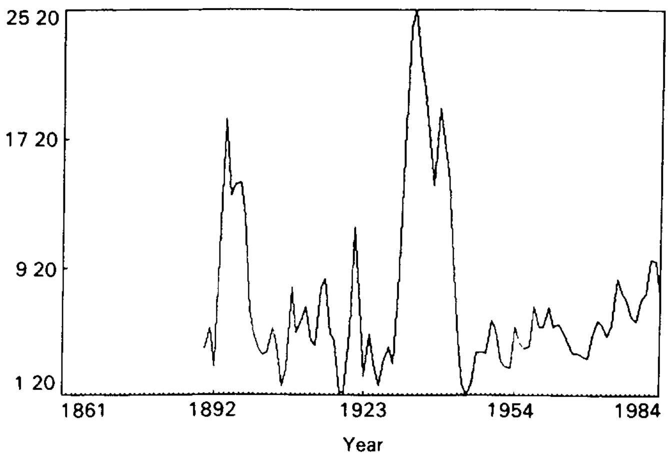

Fig. 2. *Aggregate unemployment rate, United States 1890–1984*

with slow changes occurring to levels once established. A simple AR(1) regression for Australia yielded the following results for the log of the aggregate unemployment rate (t-statistics are in parentheses):

$$\text{LUR} = \underset{(2.18)}{0.13} + \underset{(23.38)}{0.91}\,\text{LUR}(-1) \qquad R^2 = 0.82 \qquad \text{s.e.} = 0.3029$$

The results suggest substantial unemployment rate persistence. Blanchard and Summers (1986) conduct similar analyses for the United Kingdom (UK) and the USA and find comparable degrees of persistence for both countries, although the Australian unemployment rate is even slower to return to its mean value than the UK and USA unemployment rates which exhibit 'at best a weak tendency to return to... [their] ...mean.' (Blanchard and Summers, 1986, p. 21).

The unemployment rate in Australia, the UK and the US (among other Western economies) changes its level infrequently. There have been three notable rises in the level of the unemployment rate: the 1890 recession, the 1929–39 period, and the recent post-1978 period. Each time the level has risen, the unemployment rate has only slowly reverted back to the previous lower level. Once the lower level is re-established it persists until some shock occurs. It is notable that each time the rate has risen and persisted at the higher rates, there has been a substantial aggregate demand failure.

It might be argued that another feature of this historical experience shown in our plots (a feature shared by other Western nations) is that for many years the rates fluctuated within a defined band and crossed some low mark several times. Taken together with the fact that in the last 20 years the rates have been on average much higher than previously, one might conclude that a simple mean shift has occurred without resorting to any unit-root explanations.

However, Table 1 reports standard unit-root tests on the Australian and the USA data. The augmented Dickey–Fuller statistics are well below the critical values. The null hypothesis of a driftless random walk with zero mean which is tested by (Φ_2) cannot be rejected (see Section V for an explanation of this and the Φ_3-test). The related driftless random-walk hypothesis (Φ_3) also can not be rejected. Thus we cannot reject the hypothesis that the unemployment rates are unit-root processes. The first difference of the unemployment rates appears to be stationary, with the unit-root hypothesis being clearly rejected. Obviously more detailed testing is in order. We simply cannot dismiss the post-1960s period as being a case of a mean shift.

Table 1. *Annual historical unemployment rates – preliminary unit-root tests*

	ADF ($k=4$)	Φ_2	Φ_3
Australia, 1861–1984			
Level	−2.69	2.47	3.66
First difference	−6.02	12.09	18.15
USA, 1890–1984			
Level	−3.29	3.69	5.54
First difference	−5.67	10.75	16.11

IV. AUTOCORRELATIONS AND PERSISTENCE

In this section, prior to the more formal unit root testing, we explore the persistence notion more thoroughly. The data is from the quarterly main economic indicators provided on disk from the OECD. Two seasonally adjusted unemployment rate series are available from this data base: the unemployment rate as defined by each country and the OECD's standardized unemployment rate. Where possible we use the former because it usually provides a longer time-series. In some cases, due to availability, the standardized unemployment rate is used. A full range of results for both sets of series is available on request. The results for each country are qualitatively similar using either series. The log of the relevant rate is used in every case.

Table 2 shows the sample autocorrelations for each country in level form. Without any significant exception, the unemployment rates display a high degree of autoregressivity at lag one (the highest is 0.98, the lowest is 0.90), then slowly decay as the lag increases, with limited individual

Table 2. *Sample autocorrelations for LUR*

		Lag					
Country	Period	1	2	3	4	5	6
Australia	66(3)–91(3)	0.97	0.94	0.90	0.87	0.84	0.81
Austria	69(1)–91(1)	0.98	0.94	0.91	0.88	0.85	0.82
Belgium[a]	70(1)–91(3)	0.98	0.95	0.91	0.87	0.83	0.78
Canada	60(1)–91(3)	0.98	0.95	0.91	0.87	0.83	0.80
Denmark	70(1)–91(2)	0.96	0.89	0.84	0.77	0.71	0.66
Finland	60(1)–91(2)	0.97	0.93	0.88	0.83	0.77	0.72
France	67(4)–91(2)	0.98	0.96	0.94	0.92	0.90	0.87
Germany	62(1)–91(3)	0 98	0.95	0.92	0.89	0.86	0.83
Italy	60(1)–91(2)	0.98	0.96	0.93	0.91	0.88	0.85
Japan	60(1)–91(3)	0.98	0.97	0.95	0.93	0.92	0.90
Netherlands[a]	70(1)–91(2)	0.96	0.91	0.85	0.80	0.75	0.69
Norway[a]	70(1)–91(2)	0.90	0.84	0.75	0.64	0.57	0.47
Sweden[a]	70(1)–91(3)	0.93	0.84	0.73	0.61	0.51	0.41
United Kingdom	60(1)–91(3)	0.98	0.96	0.94	0.91	0.88	0.85
United States	60(1)–91(3)	0.97	0.92	0.85	0.78	0.72	0.66
Random walk[b]		0.95	0.90	0.85	0.81	0.76	0.70

[a] OECD standardized unemployment rate.
[b] From Nelson and Plosser (1982, p. 147), Table 2.

variations around this pattern. The behaviour of the time series is very similar to the ACF of a random walk. (see Nelson and Plosser, 1982, p. 147).

Table 3 reports the ACFs for the first difference for each country. With the exceptions of Italy and Japan, the first lag is significant for all countries. Although Finland and the United Kingdom display some variation, in general, the ACFs drop off rapidly at higher lags, which is consistent with stationarity. A linear filter ($\mu+\beta t$) was put through each series and the ACFs computed for the 'de-trended' residuals of each series are reported in Table 4. The resulting profiles are hardly consistent with stationarity.

Table 3. *Sample autocorrelations for* ΔLUR

		Lag					
Country	Period	1	2	3	4	5	6
Australia	66(4)–91(3)	0.35	0.15	0.15	−0.09	−0.20	−0.30
Austria	69(2)–91(1)	0.32	−0.17	−0.04	0.18	0.10	0.01
Belgium[a]	70(2)–91(3)	0.55	0.49	0.36	0.26	0.11	0.07
Canada	60(2)–91(3)	0.48	0.30	0.13	−0.03	−0.02	−0.07
Denmark	70(2)–91(2)	0.47	0.66	0.03	0.07	−0.11	−0.24
Finland	60(1)–91(2)	0.30	0.22	0.30	0.03	−0.09	−0.07
France	68(1)–91(2)	0.41	0.05	−0.01	−0.02	−0.14	−0.11
Germany	62(2)–91(3)	0.61	0.32	0.18	0.02	−0.01	−0.10
Italy	60(2)–91(2)	−0.17	0.18	0.10	−0.22	0.27	−0.18
Japan	60(2)–91(3)	−0.11	0.00	0.15	−0.06	0.01	0.15
Netherlands[a]	70(2)–91(3)	0.36	0.26	0.19	0.24	0.01	−0.06
Norway[a]	70(2)–91(3)	−0.21	0.13	0.16	−0.29	0.11	−0.01
Sweden[a]	70(2)–91(3)	0.15	0.25	0.16	0.08	0.04	0.02
United Kingdom	60(2)–91(3)	0.65	0.42	0.25	0.07	0.00	−0.14
United States	60(2)–91(3)	0.63	0.35	0.16	−0.07	−0.11	−0.09
Random walk[b]		0.25	0.00	0.00	0.00	0.00	0.00

[a] OECD standardized unemployment rate.
[b] Time aggregated random walk from Nelson and Plosser (1982, p. 148), Table 3.

Table 4. *Sample autocorrelations for de-trended LUR*[a]

		Lag						
Country	T	1	2	3	4	5	6	ADF[b]
Australia	100	0.96	0.88	0.80	0.70	0.60	0.52	−1.96
Austria	86	0.91	0.80	0.72	0.64	0.54	0.44	−2.90
Belgium[a]	87	0.97	0.93	0.87	0.81	0.75	0.68	−1.06
Canada	126	0.96	0.90	0.81	0.71	0.62	0.53	−2.99
Denmark	86	0.95	0.85	0.75	0.65	0.54	0.45	−2.12
Finland	126	0.95	0.86	0.76	0.63	0.49	0.37	−3.92
France	95	0.94	0.85	0.75	0.65	0.57	0.49	−1.00
Germany	118	0.95	0.85	0.73	0.60	0.48	0.35	−2.55
Italy	126	0.84	0.74	0.61	0.44	0.33	0.18	−3.88
Japan	126	0.91	0.83	0.76	0.68	0.62	0.54	−1.99
Netherlands[a]	86	0.93	0.86	0.77	0.68	0.59	0.50	−1.51
Norway[a]	86	0.82	0.71	0.56	0.35	0.25	0.10	−2.46
Sweden[a]	87	0.93	0.84	0.73	0.61	0.51	0.41	−2.66
United Kingdom	87	0.97	0.89	0.80	0.68	0.57	0.45	−2.67
United States	87	0.97	0.90	0.82	0.72	0.62	0.53	−2.42
Random walk[c]		0.85	0.71	0.58	0.47	0.36	0.27	

[a] OECD standardized unemployment rate.
[b] ADF regression included trend with four first differences ($k=4$).
[c] De-trended random walk – approximate expected sample autocorrelations based on Nelson and Kang (1981) from Nelson and Plosser (1982, p. 150), Table 3.1.

Table 5. *Persistance of output gaps following a 3% negative shock*

Country	Half-life of shock (quarters)	Full-life of shock (quarters)
Australia	33	179
Austria	33	>200
Belgium	23	>200
Canada	18	101
Denmark	13	76
Finland	19	100
France	42	70
Germany	17	72
Italy	98	125
Japan	44	>200
Netherlands	16	183
Norway	28	91
Sweden	7	63
United Kingdom	29	>200
United States	17	>200

To gauge how much persistence exists in the data, we estimated autoregressions for each country, testing down from a general specification to a parsimonious representation of the autoregressive component. The polynomials were solved for the steady-state unemployment rates in each country and an output gap, defined as the difference between the current and the equilibrium unemployment rate, was created by introducing a 3% negative shock. The time-paths back to equilibrium were computed and the results are shown in Table 5. All the non-reported calculations are available on request.

While the results do not discriminate between the nature of the shock, it is clear that considerable time elapses occur in all countries (except maybe Sweden) even before 1.5% of the output gap is eliminated (ceterus paribus). So even if we fail to formally establish the unit root hypothesis, in practical terms the policy implications are equivalent given the high degree of persistence evident in the data.

Convergence is slow relative to the actual frequency of shocks of this dimension experienced across the OECD block. Clearly, macroeconomic policy can be designed to minimize the costs of each shock (i.e. reduce the output gaps) before the next shock impacts. A non-interventionist policy would see the impacts of previous shocks still 'substantially' in the system as the next shock arrives. Thus, the Okun losses would be magnified.

V. TESTING FOR UNIT ROOTS

Various autoregressive representations can be used as the basis for unit-root testing. For example, Perron (1988) defines three regression equations which indicate an ordering of relevant hypotheses.

$$y_t = \hat{\alpha} y_{t-1} + \hat{u}_t \tag{8}$$

$$y_t = \mu^* + \alpha^* y_{t-1} + u_t^* \tag{9}$$

$$y_t = \tilde{\mu} + \tilde{\beta}(t - T/2) + \tilde{\alpha} y_{t-1} + \tilde{u}_t \tag{10}$$

Equation 8 is stationary if $|\hat{\alpha}| < 1$, whereas if $\hat{\alpha} = 1$, the process has a unit root and is non-stationary (see Dickey and Fuller, 1979, p. 427, Equation 1.1). Equation 9 allows for fixed drift, μ^* (Dickey and Fuller, 1979, p. 428, Equation 2.1). Equation 10 provides the framework for testing. Hypothesis A a driftless random walk $(\tilde{\mu}, \tilde{\beta}, \tilde{\alpha}) = (0, 0, 1)$, and Hypothesis B $(\tilde{\mu}, \tilde{\beta}, \tilde{\alpha}) = (\tilde{\mu}, 0, 1)$ (Dickey and Fuller, 1981, p. 1057, Equation 1.3) against a general alternative.

There is some disagreement in the literature as to the order of hypothesis testing for Equations 8–10. Dickey *et al.* (1986) believe that testing should begin with Equation 9. If Equation 9 is the valid model, such statistics would have higher power than statistics generated with Equations 8 or 10. Perron (1988) disagrees and recommends starting with Equation 10. This allows a test of the unit-root hypothesis against the obvious alternative that the series is trend-stationary. Under this alternative, Equation 9 will not be able to distinguish a unit root from a trend-stationary process. We choose to use Perron's strategy and initially test th unit-root hypothesis directly against the trend-stationary alternative.

Dickey–Fuller tests based, for example, on Equation 10 assume error homogeneity. If the residual structure is correlated, we can either change the regression framework or modify the existing statistics. Dickey and Fuller (1981) and later, Said and Dickey (1984) employ the augmented Dickey–Fuller (ADF) regression, where higher-order first differences of the variable are added to whiten the residuals. The ADF regression format employed is

$$y_t = \mu + \beta t + \alpha_1 y_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta y_{t-i} + e_t \tag{11}$$

To facilitate testing y_{t-1} is subtracted from both sides and regressed as

$$\Delta y_t = \mu^* + \beta^* t + \alpha_1^* y_{t-1} + \sum_{i=1}^{k} \gamma_i^* \Delta y_{t-i} + e_t \tag{12}$$

where $\alpha_1^* = (\alpha_1 - 1)$. The test becomes the straightforward test of $\alpha_1^* = 0$.

Phillips (1987) took the second track and developed a non-parametric approach to eliminate the dependence of the asymptotic distribution of his modified test statistics on the correlation structure of the residuals.[3]

In terms of Hypothesis A, the Dickey and Fuller (1981) ϕ_2-test is computed based on Equation 10, as is the Phillips

[3]The testing method involves the OLS estimation of an AR1 autoregression supplemented by a 'correction factor based on the structure of the residuals from this regression.' (Perron, 1988, p. 302).

Table 6. *Unit-root regressions – LUR (regression model: $y_t=\hat{\mu}+\hat{\beta}t+\hat{\alpha}y_{t-1}+e_t$)*

Country	T	$\hat{\mu}$	$t(\hat{\mu})$	$\hat{\beta}$	$t(\hat{\beta})$	$\hat{\alpha}$	$t(\hat{\alpha})$	$s(\hat{e})$	$\chi^2(4)$[b]
Australia	100	0.03	1.14	0.001	1.05	0.961	−1.359	0.080	18.69[c]
Austria	88	−0.06	−2.10	0.001	3.16	0.909	−2.791	0.071	19.14[c]
Belgium[a]	86	0.08	4.34	−0.001	2.73	1.006	−0.461	0.047	21.14[c]
Canada	126	0.05	1.52	0.000	1.97	0.963	−1.741	0.053	32.36[c]
Denmark	85	0.07	1.23	0.000	0.33	0.957	−1.353	0.137	23.50[c]
Finland	125	0.02	0.99	0.001	1.68	0.947	−1.853	0.111	33.99[c]
France	94	0.03	2.13	0.000	0.03	0.991	−0.339	0.044	18.63[c]
Germany	118	0.02	0.78	0.000	0.39	0.977	−0.900	0.114	48.79[c]
Italy	125	0.22	3.68	0.001	3.83	0.844	−3.777	0.054	17.21
Japan	126	0.00	0.29	0.001	2.44	0.925	−2.541	0.057	5.26
Netherlands[a]	85	0.13	4.31	−0.001	1.86	0.993	−0.341	0.075	6.03[c]
Norway[a]	85	−0.07	1.17	0.003	2.51	0.836	−2.659	0.143	12.99[c]
Sweden[a]	86	0.06	1.18	0.000	0.09	0.940	−1.614	0.095	12.72[c]
United Kingdom	126	0.02	1.47	0.000	1.09	0.973	−1.262	0.072	57.91[c]
United States	126	0.05	1.35	0.000	0.63	0.971	−1.345	0.056	56.16[c]

[a] OECD standardized unemployment rate.
[b] $\chi^2(4)$ is a LM test for fourth-order serial correlation.
[c] denotes LM $\chi^2(1)$ serial correlation statistically significant.

Table 7. *Dickey–Fuller joint hypothesis tests – LUR*[a]

Country	T	$\tau(\hat{\alpha})$[b]	ϕ_2[c]	ϕ_3[d]	ϕ_2*	ϕ_3*
Australia	100	−1.36	2.14	0.99	2.02	1.99
Austria	88	−2.79	3.68	5.01	3.32	4.55
Belgium[e]	86	−0.46	7.98	7.97	2.57	3.21
Canada	126	−1.74	1.60	2.06	3.30	4.89
Denmark	85	−1.35	2.19	1.72	1.82	2.37
Finland	125	−1.85	1.62	1.78	5.53	7.69
France	94	−0.34	3.79	0.74	2.17	1.05
Germany	118	−0.90	1.87	0.97	2.49	3.30
Italy	125	−3.78	5.33	7.49	5.62	7.73
Japan	126	−2.54	2.31	3.38	1.49	1.98
Netherlands[e]	85	−0.34	7.63	7.86	2.86	4.01
Norway[e]	85	−2.66	2.80	3.79	2.60	3.13
Sweden[e]	86	−1.61	1.00	1.30	2.75	4.12
United Kingdom	126	−1.26	1.86	0.80	3.01	3.67
United States	126	−1.34	0.67	0.90	2.02	3.03

[a] *ϕ_2 and ϕ_3 are based on* $y_t=\mu+\beta t+\alpha y_{t-1}+e_t$, whereas ϕ_2* and ϕ_3* are based on $y_t=\mu+\beta t+\alpha y_{t-1}+\sum_{i=1}^{k}\gamma_i\Delta y_{t-i}+e_t$, with $k=4$. The values of T are based on the model without higher-order terms.

[b] Critical values for $\tau(\alpha)$ (see Fuller, 1976, p. 381, Table 8.5.2):

$T=$	80	100	120
5% level	−3.47	−3.45	−3.44

[c] Critical values for ϕ_2 and ϕ_2* (Dickey and Fuller, 1981, p. 1063, Table v):

$T=$	80	100	120
5% level	5.03	4.88	4.86

[d] Critical values for ϕ_3 and ϕ_3* (Dickey and Fuller, 1981, p. 1063, Table vi):

$T=$	80	100	120
5% level	6.59	6.49	6.47

[e] OECD standardized unemployment rate.

and Perron (1988) $Z(\phi_2)$-statistic which is a modified version of the ϕ_2-statistic. In terms of Hypothesis B, the ϕ_3-test statistic (Dickey and Fuller, 1981) is computed based on Equation 10, along with the corresponding $Z(\phi_3)$ due to Phillips and Perron (1988). We also calculate ϕ_2^* and ϕ_3^* based on the ADF regression. A range of ADF tests (for $k=0$–4), the τ_τ-test from Fuller (1976), and the $Z(\alpha)$ and the $Z(t_\alpha)$-tests from Phillips (1987) are also reported.

VI. TEST RESULTS

The results are reported in Tables 6–8 (and the appendix). Table 7 provides statistics for the unit-root null against the general alternative in Equation 10. The Φ^*-statistics are based on the ADF regression (Equation 12), whereas the Φ-statistics are from the Dickey–Fuller (DF) regression (Equation 10). The results vary due to the impact of the

Table 8. *Phillips–Perron Z-statistics – LUR*

	Truncation lag						Truncation lag					
	2	4	6	8	10	12	2	4	6	8	10	12
			Australia						Austria			
$Z(\hat{\alpha})$	−3.93	−3.93	−3.93	−3.93	−3.93	−3.93	−8.05	−8.05	−8.05	−8.05	−8.05	−8.05
$Z(t\alpha)$	−1.71	−1.87	−1.82	−1.69	−1.63	−1.61	−2.81	−2.81	−2.83	−2.82	−2.80	−2.80
$Z(\Phi_2)$	1.39	1.17	1.23	1.41	1.53	1.56	2.92	2.92	2.72	2.88	3.09	3.34
$Z(\Phi_3)$	0.64	0.54	0.57	0.65	0.70	0.72	4.01	3.98	3.72	3.93	4.21	4.55
			Belgium[a]						Canada			
$Z(\hat{\alpha})$	0.54	0.55	0.55	0.55	0.55	0.55	−4.61	−4.61	−4.61	−4.61	−4.61	−4.61
$Z(t\alpha)$	−0.68	−0.78	−0.80	−0.78	−0.75	−0.74	−2.07	−2.20	−2.24	−2.25	−2.27	−2.27
$Z(\Phi_2)$	4.51	3.57	3.43	3.55	3.77	3.93	0.90	0.75	0.72	0.71	0.69	0.69
$Z(\Phi_3)$	4.33	3.43	3.29	3.41	3.62	3.77	1.16	0.97	0.92	0.92	0.89	0.89
			Denmark						Finland			
$Z(\hat{\alpha})$	−3.61	−3.61	−3.61	−3.61	−3.61	−3.61	−6.68	−6.68	−6.68	−6.68	−6.68	−6.68
$Z(t\alpha)$	−1.68	−1.77	−1.76	−1.63	−1.53	−1.45	−2.27	−2.58	−2.68	−2.68	−2.58	−2.44
$Z(\phi_2)$	1.37	1.23	1.25	1.47	1.69	1.89	1.05	0.80	0.74	0.74	0.80	0.90
$Z(\phi_3)$	1.08	0.97	0.99	1.16	1.33	1.49	1.15	0.88	0.81	0.81	0.88	0.99
			France						Germany			
$Z(\hat{\alpha})$	−0.89	−0.89	−0.89	−0.89	−0.89	−0.89	−2.71	−2.71	−2.71	−2.71	−2.71	−2.71
$Z(t\alpha)$	−0.81	−0.89	−0.83	−0.78	−0.76	−0.75	−1.65	−1.93	−2.03	−1.99	−1.89	−1.79
$Z(\phi_2)$	2.48	2.32	2.44	2.55	2.59	2.61	1.05	0.80	0.74	0.74	0.80	0.90
$Z(\phi_3)$	0.49	0.45	0.48	0.50	0.51	0.51	0.95	0.76	0.71	0.73	0.79	0.85
			Italy						Japan			
$Z(\hat{\alpha})$	−19.45	−19.45	−19.45	−19.45	−19.45	−19.45	−9.46	−9.46	−9.46	−9.46	−9.46	−9.4
$Z(t\alpha)$	−3.76	−3.82	−3.88	−3.83	−3.76	−3.71	−2.48	−2.54	−2.60	−2.59	−2.60	−2.6
$Z(\phi_2)$	5.51	4.99	4.64	4.93	5.46	6.02	2.62	2.31	2.09	2.11	2.09	2.2
$Z(\phi_3)$	7.73	7.01	6.52	6.93	7.67	8.45	3.83	3.38	3.07	3.10	3.06	2.92
			Netherlands[a]						Norway[a]			
$Z(\hat{\alpha})$	−0.60	−0.61	−0.61	−0.61	−0.61	−0.61	−13.96	−13.96	−13.96	−13.96	−13.96	−13.96
$Z(t\alpha)$	−0.54	−0.63	−0.61	−0.51	−0.40	−0.32	−2.56	−2.72	−2.80	−2.77	−2.70	−2.61
$Z(\phi_2)$	5.71	5.03	5.21	5.97	6.98	7.83	3.05	2.67	2.51	2.57	2.71	2.92
$Z(\phi_3)$	5.88	5.17	5.37	6.14	7.19	8.06	4.12	3.60	3.40	3.48	3.67	3.94
			Sweden[a]						United Kingdom			
$Z(\hat{\alpha})$	−5.13	−5.13	−5.13	−5.13	−5.13	−5.13	−3.39	−3.39	−3.39	−3.39	−3.39	−3.39
$Z(t\alpha)$	−1.85	−2.06	−2.17	−2.23	−2.24	−2.22	−1.87	−2.15	−2.25	−2.23	−2.15	−2.05
$Z(\phi_2)$	0.74	0.59	0.53	0.50	0.50	0.51	0.89	0.68	0.62	0.63	0.67	0.65
$Z(\phi_3)$	0.96	0.77	0.69	0.65	0.64	0.66	0.38	0.29	0.27	0.27	0.29	0.32
			United States									
$Z(\hat{\alpha})$	−3.65	−3.65	−3.65	−3.65	−3.65	−3.65						
$Z(t\alpha)$	−1.91	−2.12	−2.16	−2.15	−2.10	−2.05						
$Z(\phi_2)$	0.33	0.27	0.26	0.26	0.27	0.29						
$Z(\phi_3)$	0.44	0.36	0.35	0.35	0.36	0.39						

[a] OECD standardized unemployment rate.

residual structure on the residual sum of squares in Equation 10.

Using the Φ_2-test of the joint hypothesis of a driftless random walk against the general alternative Equation 10, we can reject the null at the 5% level for Belgium, Italy and the Netherlands (with France at the margin). However, Table 6 reveals significant first-order (except Japan and Italy) and fourth-order (except Japan) serial correlation in the DF regression. In this case, the ADF regression is the preferable framework. Accordingly, the Φ_2^*-tests suggest that we can only reject the null for Italy and Finland. The more restricted joint null of a random walk with fixed drift (Φ_3^*-test) once again adds Finland to Italy as our two TS potentiates.

Based on the Φ (and Φ^*)-tests, the majority of OECD countries examined appear to have DS unemployment rates. The $\tau(\hat{\alpha})$-test from Fuller (1976) supports this conclusion and emphasises the distinct behaviour of Italy.

The alternative method of testing the unit-root hypothesis when our regression framework is plagued by residual correlation is provided by the Phillips–Perron Z-tests. Table 8 reports the full range of Z-statistics for LUR and they are of considerable interest. The $Z(\Phi)$-tests confirm the conclusions based on the corresponding DF Φ-tests for every country bar Finland. The Z correction suggests that the null hypotheses for Finland cannot be rejected. The results are also invariant to the truncation lag chosen. The $Z(\hat{\alpha})$-test (critical values from Fuller, 1976, Table 8.5.1, p. 371, third panel) indicates that the null cannot be rejected in any case, although Italy is marginal at the 0.05 level. The $Z(t(\hat{\alpha}))$-tests confirm the results based on the $\tau(\hat{\alpha})$-test from Fuller (1976).

A complete range of DF and ADF tests are reported in the appendix. For Finland, the unit root hypothesis cannot be rejected for values of $k \leqslant 4$. While the other countries display some sensitivity to the value of k, overall the unit-root hypothesis remains the plausible working model. The ADF tests for the first difference reveal that in general, the unit-root null is rejected.

Tentatively it is concluded that except for Italy, the unemployment rates of the remaining OECD countries behave consistently with integrated processes of order one and are hence non-stationary over the sample period examined. Finland's status is questionable. In terms of our theoretical introduction, this evidence is more consistent with the widespread presence of hysteresis across the OECD block than it is with the universality of the NRH.

VII. THE SEGMENTED TREND ALTERNATIVE

Rappoport and Reichlin (1988) challenged the notion, which has become widely accepted since Nelson and Plosser published their USA findings in 1982, that macroeconomic time-series are difference-stationary processes (Perron, 1989, also questioned this idea). Their principal conclusion is that 'when the unit-root hypothesis is tested against a segmented trend hypothesis, i.e., against the hypothesis that series are dominated by large infrequent shocks, it is rejected for some of the series analysed. . .' (Reichlin, 1989, p. 231).

In this section, we introduce and test this hypothesis and gauge the results in Section V against it. We should note that the approach is *ad hoc*. No formal definition of a significant shock is advanced. Determination of the break points becomes an 'eye-balling' exercise which is rather unsatisfactory.

From Perron (1989), we consider three models: the 'crash hypothesis' where under the null of a unit root the process is augmented by a dummy variable which takes the value of one only at the time of the shock, but undergoes a permanent intercept change following the break under the (segmented) TS alternative; the 'changing growth' hypothesis which incorporates a shift in the intercept under the null, and a change in the slope of the trend function under the alternative; the hydrid model which allows a shock in the level to accompany a permanent change in the growth rate.

To motivate testing, Perron (1989, p. 1380) proposes three regressions corresponding to the three models described above.

MODEL A:

$$y_t = \hat{\mu}^A + \hat{\phi}^A DU_t + \hat{\beta}^A t + \hat{d}^A (TB)_t + \hat{\alpha}^A y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta y_{t-1} + \hat{e}_t$$

where $d(TB)_t = 1$ if $t = T_B$ and zero otherwise, $DU_t = 1$ if $t > T_B$ and zero otherwise, and T_B is the break quarter.

MODEL B:

$$y_t = \hat{\mu}^B + \hat{\phi}^B DU_t + \hat{\beta}^B t + \hat{\gamma}^B DT_t^* + \hat{\alpha}^B y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta y_{t-1} + \hat{e}_t$$

where $DT_t^* = t - T_B$ if $t > T_B$ and zero otherwise.

MODEL C:

$$y_t = \hat{\mu}^C + \hat{\phi}^C DU_t + \hat{\beta}^C t + \hat{\gamma}^C DT_t + \hat{d}^C (TB)_t + \hat{\alpha}^C y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta y_{t-1} + \hat{e}_t$$

where $DT_t = t$ if $t > T_B$ and zero otherwise.

From Perron (1989, p. 1380–81), 'The null hypothesis of a unit root imposes the following restriction on the true parameters of each model: Model A, the 'crash hypothesis': $\hat{\alpha}^A = 1$, $\hat{\beta}^A = 0$, $\hat{\phi}^A = 0$; Model B, the 'breaking slope with no crash'. $\hat{\alpha}^B = 1$, $\hat{\gamma}^B = 0$, $\hat{\beta}^B = 0$; and Model C, where both effects are allowed: $\hat{\alpha}^C = 1$, $\hat{\gamma}^C = 0$, $\hat{\beta}^C = 0$. Under the alternative hypothesis of a 'trend stationary' process, we expect $\hat{\alpha}^A, \hat{\alpha}^B, \hat{\alpha}^C < 1$; $\hat{\beta}^A, \hat{\beta}^B, \hat{\beta}^C \neq 0$; $\hat{\phi}^A, \hat{\alpha}^C, \hat{\gamma}^B, \hat{\gamma}^C \neq 0$. Finally, under the alternative hypothesis, d^A, d^C and ϕ^B should be close

Table 9. *Segmented trend tests*

Country	T	T_B	λ	$\hat{\mu}$	$\hat{\phi}$	$\hat{\beta}$	$\hat{\gamma}$	$\hat{d}$	$\hat{\alpha}$	$s(\hat{e})$	$\chi^2(4)$
Model A (15): $y_t=\hat{\mu}+\hat{\phi}DU_t+\hat{\beta}t+\hat{d}D(TB)_t+\hat{\alpha}y_{t-1}+\sum_{i=1}^{k}c_i\Delta y_{t-1}+\hat{e}_t$											
Australia	94	74(3)	0.31	0.06	0.13	0.001		0.23	0.86	0.06	22.93
($k=6$)				(2.45)	(3.47)	(1.48)		(3.16)	(−3.36)		
Australia	100	74(4)	0.32	0.08	0.14	0.001		−0.01	0.85	0.07	9.30
($k=6$)				(2.74)	(3.06)	(1.30)		(0.14)	(−3.09)		
France	90	74(3)	0.41	0.05	0.05	0.000		0.06	0.94	0.04	24.80
($k=4$)				(2.63)	(2.31)	(0.70)		(1.22)	(−1.82)		
Finland	121	75(2)	0.41	0.07	0.08	0.001		0.14	0.87	0.09	5.23
($k=4$)				(2.62)	(1.96)	(1.33)		(1.40)	(−4.16)		
Germany	114	73(3)	0.33	−0.05	0.12	0.001		0.01	0.89	0.04	2.35
($k=4$)				(1.93)	(3.23)	(2.09)		(0.08)	(−3.96)		
Japan	122	74(1)	0.32	0.03	0.11	0.000		−0.08	0.84	0.05	3.05
($k=4$)				(2.73)	(4.63)	(0.15)		(1.24)	(−4.19)		
UK	122	74(1)	0.35	0.03	0.06	0.000		−0.08	0.94	0.05	2.33
($k=4$)				(2.87)	(2.80)	(0.64)		(1.38)	(−3.04)		
USA	120	74(4)	0.11	0.11	0.02	0.000		0.15	0.93	0.04	11.09
($k=4$)				(2.82)	(1.19)	(0.27)		(3.55)	(−3.09)		
Model B (16): $y_t=\hat{\mu}+\hat{\beta}t+\hat{\gamma}DT_t^*+\hat{\alpha}y_{t-1}+\sum_{i=1}^{k}c_i\Delta y_{t-1}+\hat{e}_t$											
Australia	96	74(3)	0.31	−0.06		0.005	−0.004		0.90	0.07	3.79
($k=4$)				(0.47)		(3.10)	(2.68)		(−3.07)		
Australia	96	74(4)	0.32	−0.15		0.005	0.004		0.90	0.07	5.22
($k=6$)				(2.18)		(3.00)	(2.58)		(−2.98)		
France	88	74(3)	0.41	−0.06		0.002	−0.002		1.00	0.04	1.51
($k=6$)				(1.13)		(1.47)	(1.94)		(−0.07)		
Finland	121	75(2)	0.41	0.02		0.002	−0.001		0.87	0.10	8.22
($k=4$)				(0.83)		(2.57)	(0.99)		(−4.02)		
Germany	114	73(3)	0.33	−0.08		0.003	−0.002		0.94	0.09	6.48
($k=4$)				(2.02)		(2.60)	(1.47)		(−2.55)		
Japan	122	74(1)	0.32	−0.02		0.001	−0.001		0.95	0.06	5.44
($k=4$)				(0.99)		(2.35)	(1.60)		(−1.29)		
UK	122	74(1)	0.35	0.02		0.001	0.000		0.95	0.05	3.01
($k=4$)				(1.25)		(1.70)	(0.17)		(−2.64)		
USA	122	74(4)	0.42	0.05		0.001	−0.001		0.95	0.04	3.54
($k=4$)				(0.1.73)		(2.40)	(1.85)		(−2.27)		
Model C (17): $y_t=\hat{\mu}+\hat{\phi}DU_t+\hat{\beta}t+\hat{\gamma}DT_t+\hat{d}D(TB)_t+\hat{\alpha}y_{t-1}+\sum_{i=1}^{k}c_i\Delta y_{t-1}+\hat{e}_t$											
Australia	94	74(3)	0.31	0.02	0.22	0.003	−0.002	0.22	0.86	0.06	23.26
($k=6$)				(0.23)	(2.24)	(1.43)	(1.00)	(3.04)	(−3.39)		
Australia	94	74(4)	0.32	−0.09	0.34	0.005	−0.004	0.02	0.84	0.07	6.59
($k=6$)				(1.12)	(3.24)	(2.47)	(2.14)	(0.27)	(−3.31)		
France	89	74(3)	0.41	0.04	0.10	0.000	0.000	−0.06	0.95	0.03	14.47
($k=5$)				(0.69)	(1.48)	(0.04)	(0.30)	(1.50)	(−1.49)		
Finland	121	75(2)	0.41	0.05	0.13	0.001	−0.001	0.12	0.86	0.09	5.89
($k=4$)				(1.82)	(1.62)	(1.43)	(0.77)	(1.17)	(−4.13)		
Germany	114	73(3)	0.33	−0.05	0.11	0.001	0.000	0.01	0.89	0.08	2.39
($k=4$)				(1.16)	(1.82)	(1.06)	(0.21)	(0.08)	(−3.81)		
Japan	122	74(1)	0.32	0.04	0.09	0.000	0.000	−0.01	0.84	0.05	3.64
($k=4$)				(1.70)	(2.41)	(0.33)	(0.30)	(1.22)	(−3.16)		
UK	122	74(1)	0.35	0.05	0.03	0.000	0.000	−0.07	0.94	0.05	3.45
($k=4$)				(2.44)	(0.91)	(0.01)	(0.76)	(1.27)	(−3.13)		
USA	122	74(4)	0.40	0.08	0.05	0.005	−0.001	0.14	0.94	0.04	11.29
($k=4$)				(1.96)	(1.85)	(1.42)	(1.58)	(3.39)	(−2.71)		

to zero while under the null hypothesis they are expected to be significantly different from zero.'

Perron (1989) suggests that we employ descriptive and graphical analysis to determine which of the three models should be used for any specific time-series. Using graphical evidence, the likely candidates for structural breaks are Australia (around 1974(3)), Canada (1981(4)), Japan (1974(4)), United States (1974(4)), United Kingdom (1974(1)), France (1974(3)), Germany (1973(3)) and Finland (1975(2)). Most of the possible breaks coincide with OPEC oil shocks. The remaining countries in the study do not exhibit graphical evidence of major structural change in their unemployment rate series. The *ad hoc* nature of this approach is exemplified by this type of casual 'shock assessment'.

The value of k is determined by significance tests (at the 10% level) on the lagged first differences. Too many lagged terms decrease the power but not the size of the test, whereas too few affect the size of the test. In fact, the results presented do not depend critically on the value of K up to 8.

We test each model (A, B and C) separately for each country. By choosing arbitrary break points and testing sequentially, the problem of pre-testing (data-mining) is raised. According to Perron (1989, p. 1388), we need 'a test for structural changes in the trend function occurring at unknown dates.' Thus, care should be taken when interpreting the results of these regressions.

We begin with the general model (C) which nests both segmented trend hypotheses. Table 9 reports the results. The relevant test statistic is the t-ratio (in parentheses) corresponding to $\hat{\alpha}$ (critical values are from Perron, 1989, Table Vi.B, p. 1377). Taking note of λ (the proportion of the sample prior to the hypothesised break), the unit root null cannot be rejected in all cases. For Australia and Japan there is evidence of a changing mean, and for Australia and the USA there is evidence of a significant crash ($\hat{d}>0$).

Using Model B (see Table 9), we can only reject the null for Finland, which confirms the results from the conventional unit root tests reported earlier. If Model A is appropriate (that is, the trend function retained its slope but changed level as the alternative to the unit root hypothesis with a crash), our conclusions change somewhat. From Table 9, we now reject the null for Finland and Japan. Thus, Japan provides the sole evidence in support of the claim that the non-rejection of the unit root hypothesis is largely due to mis-specification of the original test regression.[4]

VIII. CONCLUSION

We should be clear that our study does not provide a competitive comparison between the unit-root hypothesis and the alternative of stationary fluctuations around some deterministic (linear or breaking) trend. Even if we had rejected the unit-root null, we could not have concluded that the alternative could be accepted. Moreover, even if we had found some evidence in favour of the segmented trend hypotheses this would not have implied that the secular trend and the changes it undergoes is deterministic. Otherwise, forecasting would be certain.

Further, even if the segmented trend hypothesis had empirical credence, it would not negate the policy relevance of the HH. Pagan and Wickens (1989, p. 970), in relation to Perron's (1989) claim that the unit root hypothesis is more often rejected if one accounts for shifts in the mean of the series and changes in the trend function slopes, say 'Perhaps this is not surprising as the unit root makes any shock persistent and dummy variables just do the same thing'. This amounts to a refinement of the HH. Thus, while most policy shocks have transitory effects, a large shock can have permanent effects.

An important qualification to our work comes from Blough (1988), who points out that in small samples (especially frequently sampled data), trend-stationary processes are virtually observationally equivalent to DS processes with moving average errors (with roots close to minus one).

So while our study cannot reject the unit-root hypothesis in general, we admit that the tests have low power against near unit-root processes. Combining this knowledge with the evidence that at least the unemployment rates in the OECD countries examined are highly persistent, the results of the study provide further evidence for the mounting case that cyclical shocks can have long term effects on the unemployment rates in many OECD countries. The tests on the post-1960 sample thus are not inconsistent with the tentative findings for the data samples in Section III which started in the last century.

In terms of the practical implications, a definite short term role for policy is suggested. Well designed policies aimed at reducing Okun losses following a negative aggregate shock can make permanent contributions to the social welfare of the communities in question. In a practical domain it becomes a moot point whether the roots are unit or near-unit.

An important point is that our results are not intended to explain the processes at work. We have taken the first step of measuring and providing a summary of important features of the time-series. The task ahead for labour economists is to analyse the behavioural forces at work in more theoretical terms.

[4]The ADF test, $k=4$, for the residuals from the segmented trend regression for Japan was -4.16, indicating a rejection of the null that the residuals are non-stationary.

APPENDIX

Table A1. *Dickey–Fuller unit-root tests – LUR*

Country	T^b	DF	Trend excluded ADF[c]				DF	Trend included ADF[d]			
			K=1	K=2	K=3	K=4		K=1	K=2	K=3	K=4
Australia	100	−0.93	−1.28	−1.18	−1.10	−1.17	−1.36	−2.04	−2.15	−2.50	−1.96
Austria	88	−0.15	−0.69	−0.19	−0.42	−0.56	−2.79	−2.79	−2.37	−2.57	−2.90
Belgium[a]	86	−2.70	−2.09	−3.36	−2.45	−2.46	0.46	0.50	−1.54	−1.23	−1.06
Canada	126	−0.46	−1.27	−1.45	−1.35	−1.15	−1.74	−2.85	−3.30	−3.24	−2.99
Denmark	85	−1.84	−2.23	−2.07	−2.54	−1.65	−1.35	−2.44	−2.01	−2.56	−2.12
Finland	125	−0.84	−1.36	−1.73	−2.26	−2.06	−1.85	−2.51	−3.06	−4.28	−3.92
France	94	−1.22	−0.88	−0.78	−1.02	−1.27	−0.34	−1.57	−1.25	−1.19	−1.00
Germany	118	−1.34	−1.41	−1.50	−1.32	−1.21	−0.90	−2.85	−2.63	−2.93	−2.55
Italy	125	−0.52	−0.35	−0.64	−0.87	−0.54	−3.78	−3.28	−3.32	−4.12	−3.88
Japan	126	−0.89	−0.77	−0.77	−0.96	−0.98	−2.54	−2.48	−2.28	−2.27	−1.99
Netherlands[a]	85	−3.54	−3.50	−3.46	−3.03	−2.84	−0.34	−1.16	−1.46	−1.32	−1.51
Norway[a]	85	−1.09	−0.59	−0.84	−1.55	−1.03	−2.66	−2.19	−2.45	−3.23	−2.46
Sweden[a]	86	−1.62	−1.99	−2.52	−2.89	−2.73	−1.61	−1.98	−2.51	−2.88	−2.66
UK	126	−0.65	−1.36	−1.31	−1.44	−1.39	−1.26	−2.91	−3.13	−3.09	−2.67
USA	126	−1.19	−2.55	−2.35	−2.24	−1.80	−1.34	−2.92	−2.81	−2.95	−2.42

[a] OECD standardized unemployment rate.
[b] The number of observations, T is for the DF regression. To derive the value of T for the ADF regression subtract k from T.
[c] Regression model is: $y_t = \mu + \alpha y_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta y_{t-1} + e_t$
[d] Regression model is: $y_t = \mu + \beta t + \alpha y_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta y_{t-1} + e_t$

Table A2. *Dickey–Fuller unit root tests – ΔLUR*

Country	T^b	DF	Trend excluded ADF[c]				DF	Trend included ADF[d]			
			K=1	K=2	K=3	K=4		K=1	K=2	K=3	K=4
Australia	99	−6.89	−5.35	−4.18	−4.68	−4.87	−6.87	−5.33	−4.14	−4.67	−4.91
Austria	87	−6.64	−7.43	−4.84	−3.72	−3.49	−6.66	−7.50	−4.90	−3.79	−3.54
Belgium[a]	85	−4.93	−3.64	−2.91	−2.87	−3.16	−5.53	−4.78	−3.66	−3.74	−4.44
Canada	125	−6.67	−5.24	−4.93	−5.02	−4.26	−6.72	−5.32	−5.01	−5.09	−4.34
Denmark	84	−5.47	−5.67	−4.26	−3.75	−4.20	−5.54	−5.78	−4.44	−3.73	−4.30
Finland	124	−7.87	−5.19	−3.36	−3.69	−4.03	−7.83	−5.16	−3.33	−3.66	−3.93
France	93	−6.22	−6.08	−4.78	−4.33	−4.52	−6.20	−6.06	−4.83	−4.44	−4.66
Germany	117	−5.36	−5.12	−4.46	−4.71	−3.91	−5.34	−5.13	−4.44	−4.69	−3.94
Italy	124	−13.22	−7.29	−5.01	−5.64	−4.31	−13.22	−7.28	−5.00	−5.66	−4.27
Japan	125	−12.36	−8.26	−5.70	−5.30	−4.56	−12.34	−8.24	−5.67	−5.27	−4.55
Netherlands[a]	84	−6.03	−4.16	−3.36	−2.60	−2.94	−7.23	−5.38	−4.45	−3.57	−4.25
Norway[a]	84	−11.25	−6.36	−4.14	−4.83	−4.29	−11.28	−6.40	−4.13	−4.82	−4.36
Sweden[a]	85	−7.76	−4.47	−3.34	−3.14	−3.07	−7.72	−4.44	−3.28	−2.93	−2.76
UK	125	−5.14	−4.49	−4.27	−4.57	−4.09	−5.13	−4.46	−4.26	−4.58	−4.09
USA	125	−5.26	−5.15	−5.12	−5.65	−4.55	−5.24	−5.13	−5.09	−5.63	−4.53

[a] OECD standardized unemployment rate.
See explanatory notes in Table A1. The regressions noted are in first differences.

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