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Lewis Evans

Neil Quigley

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**Lewis Evans
and
Neil Quigley**

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What Can Univariate Models Tell Us About Canadian Economic Growth 1870 - 1985?*

Lewis Evans

Department of Economics
Victoria University of Wellington
P O Box 600
Wellington, NZ

Neil Quigley

Department of Economics
University of Western Ontario
London, Ontario N6A 5C2
and
Victoria University of Wellington

November 1992

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Abstract

Inwood and Stengos (1991) applied the recent developments in unit root econometrics by Perron (1989) to Canadian real GNP and investment data, and argued that the wheat boom, WWI and WWII resulted in permanent exogenous shocks to the Canadian economy, but the great depression and the oil price shocks did not. We show that this methodology can be used to support a large number of plausible alternative hypotheses about exogenous shocks to the Canadian economy, and discuss a number of the important theoretical shortcomings associated with it. In addition, application of an alternative approach to the analysis of univariate time series (Harvey and Jaeger 1991) suggests that the Perron model may mis-specify the trend in the Canadian data, and that the conclusions drawn from it may be spurious. We therefore argue that univariate econometric models have very limited power to distinguish between the alternative hypotheses about long-run growth that are of interest to economic historians.

Introduction

The development of unit root econometrics in the last decade has stimulated a large volume of empirical and theoretical research on the time-series properties of macroeconomic variables.¹ The hypothesis that real GNP and other variables are not stationary because they contain a unit root implies that certain exogenous shocks may have permanent effects on the economy and cannot be represented as transitory cycles around a more or less stable trend path. Perron (1989) has contributed to the development of this theory by arguing that exogenous shocks that have permanent effects are rare, so that unit roots may be removed from macroeconomic time series by inserting structural breaks in the years at which the exogenous shocks occur. His approach is to model univariate macroeconomic time series as a linear deterministic trend, with structural breaks, and a stationary stochastic component.

Inwood and Stengos (1991) (IS) apply Perron's approach to Canadian real GNP and investment data for the period since 1870. They conclude that Canada's economic growth can be decomposed into three episodes represented as the sum of a linear deterministic trend, with breaks at 1896, 1914 and 1939, and a stationary stochastic process. They argue that this suggests that each of the wheat boom, WWI and WWII were exogenous shocks that resulted in permanent deviations from the trend rate of growth, while the depressions of the 1870s and 1930s, the oil price shocks of the 1970s and other events were either transitory in their impact or endogenous to the process of Canadian economic growth.

We argue that the IS application of the Perron methodology and the conclusions that they draw from their results are flawed. We show that there are a large number of equally plausible representations of the data that incorporate breaks in different years, particularly 1929, and that the results exhibit some sensitivity to small changes in both the sample of the data used and the truncation lag parameter in the model. In addition, we use an alternative approach to the analysis of the time-series properties of the data (Harvey and Jaeger, 1991) to demonstrate that the trend in Canadian GNP may be more correctly represented as stochastic. This means that conclusions derived from the application of the Perron methodology may be based on a model in which the trend is mis-specified, and thus be spurious. We conclude that the Perron methodology does not have the power to discriminate between alternative theories of Canadian economic

¹ The development of this methodology is described in the surveys of Granger (1986), Hendry (1986), Diebold and Nerlove (1990), and Campbell and Perron (1991).

growth and, more generally, that economic historians should be very cautious about the use of unit root tests to discriminate between different hypotheses.

Application of the Perron Model to Canadian Economic Growth

The model testing for one exogenous shock is described by Perron (1989), and IS extend it to incorporate up to three break years.² The general form of the model is

$$y_t = \alpha(t) + \beta(t) + y_{t-1} + \varepsilon_t$$

under the null of a unit root, and

$$y_t = \alpha^*(t) + \delta(t)t + \varepsilon_t$$

under the alternative of a (deterministic) trend stationary process. In these equations $\alpha(t)$ and $\alpha^*(t)$ are step functions which permit the constant terms to be different between each period of structural change, $\beta(t)$ denotes a set of dummy variables, one for each observation of structural change, and $\delta(t)$ is a step function allowing the trend to differ between periods of structural change. The disturbance term follows an ARMA process of possibly unknown orders. To allow for this we adopt the Dickey and Fuller (1979) parametric correction of including lagged differences of the dependent variable thus

$$y_t = \alpha(t) + \beta(t) + \rho y_{t-1} + \sum_{j=1}^k \psi_j \Delta y_{t-j} + \varepsilon_t$$

where k is determined according to the suggested procedure of Campbell and Perron

² Under the Perron (1989) and IS (1991) approaches the break years must be chosen by the researcher. The significant statistical problem of pre-testing arises when the data are asked to reveal the break year (Christiano (1992)), as might be done, for example, by applying Perron (1989) to different potential break years. Zivot and Andrews (1992) propose a method of testing for one break year in a data series where the break is endogenous in that it is chosen by the statistical procedure. While their procedure solves the pre-testing problem, it cannot be applied directly to examine the presence of multiple break years without re-introducing the pre-testing issue. The approach of Liu (1992), in which he applies Zivot and Andrews (1992) sequentially, suffers from this difficulty. This approach involves selecting an initial break point, and then subsequently testing for a second break point conditional on there being a break at the first year selected. The presumption that the best model with m breaks will necessarily incorporate the best $m - 1$ break model appears to us to be unjustified. The flaws in this approach are well illustrated by the fact that it would not find the 1896, 1914, 1939 combination reported by IS; because the model for 1929 generates by far the strongest single break test statistic, this approach would require that it be included in all subsequent multiple break models tested.

(1991: 155).³ This involves choosing an upper bound for k ($k_{\max}$) and estimating the equation by ordinary least squares with $k = k_{\max}$. If the standard asymptotic t -statistic suggests that $\psi_{k_{\max}} \neq 0$ then analysis should proceed with $k = k_{\max}$. If the statistic suggests that $\psi_{k_{\max}} = 0$, then k is reduced by 1 and the procedure repeated. Repetition occurs until the t -statistic suggests that $\psi_{k_{\max}} \neq 0$. If no significant t -statistics are found, $k = 0$.

New estimates of national income in the period 1870 - 1926 (Urquhart, 1986, 1988) have greatly improved the quality of the data available for the study of these episodes in Canadian economic history, and resulted in increased interest in the application of modern econometric techniques to long-run Canadian macroeconomic data. Applying the Perron methodology to these data, IS clearly demonstrate that GNP and investment may be characterised as trend-stationary with structural breaks in 1896, 1914 and 1939. But they go further in arguing that this finding implies "...that there are no no other exogenous shocks with permanent impact. By implication, therefore, neither of the two great depressions, (1870s and 1930s) nor the 1973 oil shock can be viewed as an exogenous shock responsible for a change in the trend rate of growth" (1991: 280). Consequently, they argue that the great depressions and the oil price shock were either endogenous to the Canadian economic growth process or, if they were exogenous, transitory in their impact.

The unit root literature contains a number of attempts to use the distinction between trend and difference stationary representations of macroeconomic time series to differentiate between alternative models of economic processes (for example, Nelson and Plosser, 1982; Deaton, 1987). The use of the Perron methodology to test alternative hypotheses about economic growth in small open economies such as Canada has particular superficial appeal because accounts of their economic history so frequently focus on exogenous shocks as the source of large changes in rates of growth. But if the IS results were to be interpreted as the conjunction of statistics and economic history which definitively describes the Canadian growth experience, they would be surprising. Setting the claim that the great depression was endogenous to Canadian economic growth alongside the conclusions of Perron (1989) that many US macroeconomic time series can be represented as trend stationary with a persistent

³ The Campbell and Perron (1991) approach that we have adopted is also utilised by Zivot and Andrews (1992:255). IS (1991: 284) use an alternative method, based on tests for lags in the model and serial correlation in the residuals.

exogenous shock in 1929 constitutes a major reinterpretation of international economic history in the interwar period.

In our view there is a crucial flaw in the reasoning employed by IS to link their empirical results with their conclusions. The Perron methodology is designed to test whether a particular break or combination of breaks removes the unit root from a data series, but accepting one hypothesis does not rule out the possibility that alternative models fit the data equally well. There is nothing in this approach to preclude testing a range of different hypotheses, and nothing to suggest that there will be a unique "correct" representation of the data that is clearly superior to all others. So while the technique does not allow us to test for all combinations of breaks in the model⁴, it is possible to use it to examine a more comprehensive range of years in which the literature on Canadian economic history suggests that possible exogenous shocks occurred.

In addition, the IS conclusions may be challenged because it is not at all clear how we should interpret the claim that an event is exogenous or endogenous. This is because this claim only has any meaning in the context of the particular univariate model estimated, and in the absence of an explicit structural representation of the data generating process, is impossible to translate into any meaningful interpretation of the economic factors discussed in the relevant literature. Perron (1989) defines exogenous shocks as events that "were not a realization of the underlying data-generating mechanism...". This use of the term exogenous is simply "a device to remove the influence of these shocks from the noise function", and does not imply a descriptive model of the data generating mechanism (which is simply assumed to be determined by economic fundamentals which may be considered constant over long periods of time).

Univariate modelling procedures such as that developed by Perron may therefore be interpreted as accommodating the existence of the complex multivariate structures that determine the trend in macroeconomic variables, but make no attempt to formally embody such relationships in the model. This means that the distinction between exogenous and endogenous shocks cannot be defined in terms of the presence or absence of feedback from the particular variables making up the underlying data generating mechanism. Tests for unit roots and measures of persistence in univariate models are therefore very different from the multivariate prediction shocks identified in multivariate representations such as VAR models. Multivariate models produce much richer dynamics and therefore provide much more bases from which to consider the

⁴ Not least because of the pre-testing issues that it raises (see Christiano (1992)).

origins of trend and stationary components in data series (Harvey and Stock, 1988), and to define exogenous and endogenous variables. In fact, because univariate models cannot take account of behavioural links between different variables, explicit multivariate modelling of the processes generating economic growth may result in quite different conclusions about the exogeneity of shocks from those reached using univariate models. That this may have important implications for empirical findings has been demonstrated by Christiano and Eichenbaum (1990), and by Quah's (1990) resolution of the paradox observed in Deaton's (1987) univariate analysis of the movement of consumption relative to income. As a result, some very recent research has focussed on multivariate unit root methods (Campbell and Perron 1991:142), but univariate work has continued.

In the light of the discussion above it will also be clear that any choice of break years will be arbitrary in the sense that we have to adopt a definition of exogenous without having formally specified a model which can explicitly incorporate this definition. We chose to test for breaks in years for which there was clear a-priori evidence that an international event had impacted upon the Canadian economy. Using the Urquhart (1986, 1988) data on real GNP and real gross fixed capital formation we therefore tested one two and three breaks models of the different combinations of the following dates:⁵

- 1896 - beginning of the wheat boom
- 1914 - WWI
- 1920 - post-WWI recession
- 1929 - great depression
- 1939 - WWII
- 1949 - post-war boom
- 1973 - end of Bretton Woods and the beginning of oil price rises.

While the Canadian literature does not treat endogenous forces as irrelevant to the determination of domestic economic performance during the depression of the early 1930s, the great depression is uniformly regarded as the single most important exogenous shock to hit Canada during the 20th century (Bothwell et. al. 1987, 245-258; Easterbrook and Aitken 1956, 492- 4; Marr and Paterson 1980; Pomfret 1981, 184-187; Safarian 1970). The reduction in income created by falling primary product prices and the introduction of tariffs in the US is usually viewed as the primary

⁵ To ensure that our work is directly comparable, the results reported in this paper are for data supplied by Kris Inwood.

mechanism by which the depression was transmitted to Canada and other small open economies. In addition, instability in the international economy and the abandonment of the gold standard resulted in an increase in real interest rates and capital outflow which together reduced the level of new investment in Canada.

We include the wheat boom because of its significance in Canadian literature, but noting that the a-priori evidence linking it to international economic events rather than domestic Canadian development may be weaker than for any of the other shocks identified. The focus on external demand characteristic of the literature written in the staples tradition, and the so-called "revisionist" view of those who have emphasised more gradual development in agriculture and manufacturing in central Canada, have often been characterised as representative of two extremes of the exogenous vs endogenous debate about the impact of the wheat boom on Canadian economic growth. But the best of the more modern literature provides a more cautious and comprehensive view of the role of exogenous and endogenous factors. Urquhart (1986) concluded that "the Canadian economy developed in a fundamentally different way after 1900 than it had before" with higher levels of capital formation, particularly in manufacturing, and attributes much of the change to intensive agricultural settlement of the prairies. This description of structural change does not necessarily imply that its cause was exogenous. In fact, the importance of investment in railway infrastructure in reducing farm gate prices and establishing a farming frontier in the west may be interpreted as supporting the interpretation that the wheat boom was primarily endogenous to the process of Canadian economic growth, even if technological change in transportation was exogenous.⁶

Search for Break-Years

We began by setting $k_{\max} = 5$ and conducting tests to establish the appropriate value of k for models of the real GNP and gross fixed capital formation series (Table 1).⁷ The statistics of interest are those denoted t . For real gross capital formation the result was clearcut. The appropriate lag parameter is $k = 1$ because of the marked fall in the t values when $k = 2$, and their uniform strength when $k = 1$. For real GNP the appropriate choice was less clear because the increase in the t ratios as k was reduced was much less marked. We made the decision to adopt $k = 3$ as the truncation lag parameter based on the existence of some marginally significant t ratios.

⁶ On Canada see Lewis and Robinson (1984) and on the international context see Harley (1980).

⁷ All empirical work entailing testing for break years was undertaken using the econometric package, SHAZAM, of White (1990).

Table 1

Tests to Determine the Truncation Lag Parameter (k)^a**(i) Canadian Real GNP 1870 - 1985^b**

<u>Break Points</u>	<u>k = 4</u>		<u>k = 3</u>		<u>k = 2</u>	
	<u>t^c</u>	<u>Test Statistic</u>	<u>t^c</u>	<u>Test Statistic</u>	<u>t^c</u>	<u>Test Statistic</u>
1896 1914 1939	0.48	- 6.01*	1.99	- 6.62*	2.97	- 6.39*
1929	0.62	- 4.81*	1.19	- 5.13*	1.97	- 5.02*
1896 1929	0.13	- 5.05*	1.22	- 5.43*	2.10	- 5.35*
1929 1949	0.33	- 4.68	0.80	- 5.18*	1.68	- 5.23*
1929 1973	0.01	- 5.14*	1.06	- 5.49*	1.84	- 5.44*
No Break	- 0.95	- 2.67	0.15	- 3.01	1.07	- 3.08

(ii) Real Gross Capital Formation in Canada 1870 - 1985^b

<u>Break Points</u>	<u>k = 2</u>		<u>k = 1</u>		<u>k = 0</u>	
	<u>t^c</u>	<u>Test Statistic</u>	<u>t^c</u>	<u>Test Statistic</u>	<u>t^c</u>	<u>Test Statistic</u>
1896 1914 1939	0.31	- 4.66	5.43	- 5.17*	14.17	- 3.18
1929	0.06	- 4.37	5.89	- 4.69*	20.14	- 3.15
1896 1929	0.19	- 4.91*	5.73	- 5.35*	19.16	- 3.87
1929 1949	0.17	- 4.25	5.02	- 4.73	19.17	- 3.25
1929 1973	0.09	- 4.85*	5.66	- 5.19*	18.96	- 3.82
No Break	0.68	- 2.90	5.46	- 3.24	26.90	- 2.04

Notes:

- a - k defines the highest order of Δy_{t-k} used in the models.
- b - In each case the data were sampled to select the maximum number of observations given the values of k considered in this table; 6 - 116 for GNP and 4 - 116 for capital formation.
- c - t statistics are for Δy_{t-k} .
- * - Significant at 5%.

Table 2
Test Statistics for Models with One Break

<u>Break Point</u>	<u>Real GNP^a Test Statistic</u>	<u>Real Gross Fixed Capital Formation^b Test Statistic</u>
1896	- 2.93	- 3.38
1914	- 3.16	- 2.00
1920	- 3.96	- 3.89
1928	- 5.08*	- 1.90
1929	- 5.12*	- 4.66*
1930	- 4.88*	- 4.38*
1939	- 3.27	- 1.76
1947	- 3.60	- 3.65
1949	- 3.53	- 3.68
1973	- 2.90	- 3.18

Notes:

* Significant at 5% - critical value - 4.24

a k = 3; sample 5 - 116

b k = 1; sample 3 - 116

Table 3
Test Statistics for Models with Two Breaks

<u>Break Points</u>	<u>Real GNP^a Test Statistic</u>	<u>Real Gross Fixed Capital Formation^b Test Statistic</u>
1896 1914	- 3.29	- 4.28
1896 1920	- 3.64	- 3.98
1896 1929	- 5.46*	- 5.38*
1896 1939	- 4.04	- 4.72
1896 1949	- 4.03	- 4.87*
1896 1973	- 2.92	- 3.42
1914 1929	- 4.76	- 4.32
1914 1939	- 4.70	- 3.93
1914 1949	- 3.38	- 3.69
1914 1973	- 2.92	- 3.62
1920 1929	- 5.08*	- 4.68
1920 1939	- 4.89*	- 4.28
1920 1949	- 3.96	- 4.07
1920 1973	- 3.87	- 3.93
1929 1939	- 4.41	- 3.90
1929 1949	- 5.18*	- 4.69
1929 1973	- 5.47*	- 5.15*
1939 1949	- 2.95	- 3.52
1939 1973	- 3.32	- 3.55
1949 1973	- 3.58	- 3.67

Notes:

* Significant at 5% - critical value - 4.85

The choice of break point is made more difficult in those cases where the literature provides alternative theories about the year in which exogenous changes to the Canadian economy may be identified. To evaluate the sensitivity of our tests to the precise choice of year, we tested each of 1928, 1929 and 1930 as potential break points for the great depression, and both 1947 and 1949 as potential dates for the beginning of the post-war boom (Table 2). The test statistics for the models with breaks at 1947 and 1949 were very similar but not significant.⁸ We found test statistics above the 1% critical values for both 1928 and 1929, and in addition 5% for 1930. This suggests that the findings are not particularly sensitive to the precise year in which the exogenous shock is identified, and in this case it would be possible to date the origins of the great depression from the withdrawal of capital from Europe and the onset of recession in 1928, or events in the US in 1929, without seriously changing the results. However, it also provides a hint that the methodology does not have the power to clearly distinguish between alternative hypotheses about the origins of events such as the great depression or about the years in which they first impacted on Canada.

The results of our tests for one-break models for all of the chosen years (presented in Table 2) are in marked contrast to the claims of IS and provide strong support for the view that macroeconomists could reasonably treat the Canadian data as trend stationary with a one-time break in 1929. The strength of this result might be considered to call into question the utility of tests for additional breaks. But, as we have argued, there is no a priori reason to presume that the result presented by IS will be unique, neither does our result for a single break model focussing on the great depression preclude other breaks. In addition, if the IS approach has value, additional information about Canada's growth experience may be obtained by examination of other hypotheses about the time series properties of the data.

For GNP there are five two-break combinations of the exogenous shocks that we have identified which provide tests statistics large enough to reject the presence of a unit root at the 5% level (Table 3). Four of these models have the great depression as one break year, and three (1920 and 1929; 1929 and 1949; 1929 and 1973) contain none of the years on which IS focus. For real capital formation there are three significant models. Two contain 1896 (but not in combination with either 1914 or 1939) and two contain 1929.

⁸ We report only the test statistics, the equations will be supplied upon request. The test statistics should be interpreted as for standard Dickey-Fuller unit root tests. We follow IS in using the maximum critical values computed in the Monte Carlo simulations reported by Perron (1989) for one break and Inwood and Stengos (1989, 1991) for two and three breaks.

Table 4
Test Statistics for Models with Three Breaks

<u>Break Point</u>			<u>Real GNP^a</u> <u>Test Statistic</u>	<u>Real Gross Fixed Capital Formation^b</u> <u>Test Statistic</u>
1896	1914	1929	- 5.90*	- 5.63*
1896	1914	1939	- 6.63*	- 5.20*
1896	1914	1949	- 3.74	- 5.10
1896	1914	1973	- 3.81	- 4.23
1896	1920	1929	- 5.30*	- 4.98
1896	1920	1939	- 5.41*	- 4.52
1896	1920	1949	- 3.68	- 4.32
1896	1920	1973	- 3.54	- 4.03
1896	1929	1949	- 5.51*	- 5.60*
1896	1929	1973	- 5.91*	- 6.03*
1896	1939	1973	- 4.14	- 4.92
1914	1929	1949	- 4.72	- 4.30
1914	1929	1973	- 5.10	- 4.91
1914	1939	1973	- 4.92	- 4.15
1914	1949	1973	- 3.45	- 3.70
1920	1929	1939	- 4.37	- 3.86
1920	1929	1949	- 5.15*	- 4.73
1920	1929	1973	- 5.50*	- 5.34*
1920	1939	1949	- 4.31	- 4.53
1920	1939	1973	- 5.09	- 4.49
1920	1949	1973	- 5.36*	- 4.11
1929	1939	1949	- 3.69	- 4.09
1929	1939	1973	- 4.63	- 4.10
1929	1949	1973	- 5.35*	- 4.70
1939	1949	1973	- 2.85	- 3.51

Notes:

* Significant at 5% - critical value - 5.13

a k = 3; sample 5 - 116

b k = 1; sample 3 - 116

Figure 1

*Canadian (Log) GNP: 1870-1985
and Trend with 1929 Break*

Our tests of three-break representations of GNP confirm the strength of the IS finding for the combination of 1896, 1914 and 1939 (Table 4). But there are 9 other combinations that also yield significant statistics, and the most commonly represented years are 1896, 1920, 1929, 1949 and 1973. For capital formation there are five significant combinations, of which 1896, 1929 and 1973 is the most significant and the IS model of 1896, 1914 and 1939 is the most marginal.⁹

Discussion and Interpretation of the Break-Year Results

Our results from the application of the Perron model re-affirm the validity of representing Canadian GNP and investment data as trend stationary with a break in 1929 (see Figure 1¹⁰). Taken at face value, they might be interpreted as confirming the view that the great depression represents the single most persistent exogenous shock to Canadian growth and investment experienced over the period 1870-1985.¹¹ But there is also support for the view that the wheat boom was a persistent exogenous shock, but only when 1896 is combined with other break years. In the multiple break models there is also some evidence that the post-World War One recession, the post-World War Two boom, and the first oil shock were persistent exogenous shocks. The evidence in support of the suggestion that the wars represented persistent exogenous shocks is less impressive. In general, therefore, we take the view that the most important aspect of our results is the demonstration of the range of (often competing) hypotheses that can be supported by alternative (plausible) representations of the same data. These findings alone appear to fully justify the extreme scepticism about the power of unit root tests to distinguish between alternative hypotheses expressed in some of the theoretical literature (Christiano and Eichenbaum 1990, in particular), but there are a number of other important concerns about the interpretation of our results to be considered.

Our results are conditional on our choice of break date, and could only be made unconditional by the development of a direct test for structural change in the trend

⁹ Our result for the 1896, 1914 1939 model of capital formation differs from that reported in IS in two respects. First, and most importantly, they used only data to 1975 to calculate their result even though they used data to 1985 for their model of real GNP. Second, they used $k = 2$ rather than $k = 1$.

¹⁰ The trend in Figure 1 represents the long-run trend calculated by setting the Δy 's = 0, and dividing the equation by $(1-\rho L)$ where the estimated ρ is used. The trends portrayed in the graph provided by IS (1991:275) appear to be based on an inappropriate treatment of the coefficient on lagged y .

¹¹ This conclusion is confirmed by two recent applications of the Zivot and Andrews (1992) approach to the Canadian data. Liu (1992) finds that 1929 generates the strongest single-break test statistic in the real GNP data, and Raj (1992) finds that the strongest break-year statistic in Canadian GNP per head data occurs in 1930.

function occurring at unknown dates. In practice, of course, the assumption of exogeneity is violated by the pretesting involved in inspection of the data that preceded the choice of break date, but we have followed Perron (1989) and IS in not addressing the implications of the pre-test bias inevitably associated with the choice of break year for our analysis in an analytical manner. Christiano (1992) has provided an indication of the implications of the pre-test bias associated with this methodology for the critical values used to assess the test statistics. Recent attempts to "endogenise" the choice of a single break point by selecting the largest test statistic in the data and incorporating the impact of this methodology in the calculation of the critical values (Christiano 1992, Zivot and Andrews 1992) have indicated that the evidence in support of the Perron methodology is much weaker than earlier studies suggested. Extension of this approach to multiple break models cannot yet be done without re-introducing the pretesting problem.

There is increasing appreciation that long spans of data are required for unit root tests to possess any power.¹² Christiano and Eichenbaum (1990), and Campbell and Perron (1991) argue that in finite samples unit root and trend stationary models cannot be distinguished. This observational equivalence means that for every finite data series there exists an infinite number of plausible decompositions into permanent and temporary shocks, some of which make the permanent component of shocks arbitrarily small (Christiano and Eichenbaum (1990, 10-11)). This has important implications because it makes it clear the results presented by IS, and in other recent pieces of cliometrics using related approaches (for example, Crafts et al, 1989), are extremely sensitive to the assumption that the correct representation of the data has been employed. If this is not true, the conclusions may be spurious. A related issue is that tests for unit roots may tell us nothing about the shape of the impulse response function associated with an exogenous shock except that its limit is non-zero (Cochrane 1991; Hansen and Sargent 1991). This means that only when we work with an infinite horizon can we be sure that the most persistent shocks will necessarily be those shocks that have the greatest impact on the rate of economic growth.

To demonstrate the importance of these concerns about the use of finite data sets and to consider the robustness of the findings regarding the break years, we investigated the sensitivity of our results to changes in the sample of the data used. The evidence presented in the appendix should be interpreted recognising that there will be some inherent variation in the test statistics of the different sample periods which can be

¹² Sampling the same span with increasing frequency will, in many circumstances, not improve the power of unit root tests (see Perron, 1991).

expected merely because of the distribution of these statistics. Given this fact, the data illustrates the robustness of our conclusions to changes in the sample used. Whereas the GNP results are consistent, there is some variation in the capital statistics which might portend some instability. The sample from 1875 - 1975 gives the strongest break-point results for capital. The results appear more marginal for the sample 1880 - 1975. The strength of the test statistic obtained by IS for the 1896, 1914 and 1939 model of capital formation is somewhat sensitive to their decision to truncate the data in 1975.

We also check the robustness of our results with respect to the choice of lag length. That this is an issue of some substance is apparent from Table 1.¹³ While our lag length for GNP, $k = 3$, does not yield importantly different results from those reported by IS (1991) with $k = 2$, the results for real gross fixed capital formation do exhibit some variation. In contrast to our model which has $k = 1$, the test of the model with breaks at 1896, 1914 and 1939, does not reject the presence of a unit root at the 5 percent level when $k = 2$ as in IS. Our capital data series has eleven more observations than that used by IS. In this series $k = 1$ appears to be the appropriate length of lag.

Stochastic vs Deterministic Representation of the Trend

Up to this point our analysis has not considered directly the strength of the evidence supporting the presumption associated with the adoption of the Perron methodology that the trend in Canadian real GNP and real gross fixed capital formation is correctly represented by a deterministic rather than a stochastic trend. From among the variety of possible approaches through which we might have addressed this issue, we chose to utilise the structural model of Harvey and Jaeger (1991). It utilises the traditional approach of decomposing time series into trend and cyclical components. In particular, it incorporates a trend and cycle which may be stochastic. While this approach does not avoid all of the difficulties addressed in our discussion, it has the important advantage that it does not insist that the specification of the trend and any break dates be chosen exogenously by the researcher. The full model is

$$y(t) = \mu(t) + \psi(t) + \varepsilon(t) \quad \varepsilon(t) \sim \text{NID}(0, \sigma_\varepsilon^2)$$

$$\begin{aligned} \text{where } \mu(t) &= \mu(t-1) + \beta(t-1) + \eta(t) & \eta(t) &\sim \text{NID}(0, \sigma_\eta^2) \\ \beta(t) &= \beta(t-1) + \zeta(t) & \zeta(t) &\sim \text{NID}(0, \sigma_\zeta^2) \end{aligned}$$

¹³ Christiano (1992: 248) reports finding sensitivity to length of lag in his analysis of US macroeconomic time series of similar span to our data.

$$\begin{aligned} \psi(t) &= \rho \cos \lambda \psi(t-1) + \rho \sin \lambda \psi^*(t-1) + \omega(t) & \omega(t) &\sim \text{NID}(0, \sigma_\omega^2) \\ \text{and } \psi^*(t) &= \rho \sin \lambda \psi(t-1) + \rho \cos \lambda \psi^*(t-1) + \omega^*(t) & \omega^*(t) &\sim \text{NID}(0, \sigma_\omega^2). \end{aligned}$$

The, possibly, stochastic trend component is $\mu(t)$, and $\psi(t)$ is the, possibly, stochastic cycle. The damping factor is $\rho \in [0,1]$, and the frequency of the cycle measured in radians is λ . The disturbance terms are assumed to be uncorrelated. It is not our purpose to dwell on the specification of this model except to indicate that under the stricture of the error term structure many models are obtained as restricted versions (Harvey and Jaeger (1991)). In particular if $\sigma_\eta^2 = \sigma_\zeta^2 = 0$ then the trend is linear and deterministic as $\mu(t) = \mu(0) + \beta t$. The widely-used Hodrick-Prescott filter is obtained by excluding the cyclical component, $\psi(t)$, and setting $\sigma_\eta^2 = 0$.

Application of the STAMP (Harvey 1989) programme to the Canadian GNP data yielded the parameter values $\{\hat{\sigma}_\epsilon^2 = 0.0 \text{ (1.0)}, \hat{\sigma}_\eta^2 = 0.002 \text{ (0.001)}, \hat{\sigma}_\zeta^2 = 0.0 \text{ (1.0)}, \hat{\sigma}_\omega^2 = 0.0004 \text{ (0.0004)}, \hat{\rho} = 0.95 \text{ (0.05)}, \hat{\lambda} = 0.44 \text{ (0.05)}\}$ where the standard errors are presented in parentheses.¹⁴ They suggest that all the variances except that of the random-walk component of the trend can be taken to be zero. The period over which the cycle begins and ends is $14.4 (= 2\pi/\hat{\lambda})$ years and the dampening factor, $\hat{\rho}$, has a very weak effect on the cycle.¹⁵ Despite their use of quarterly data, which may yield cycles of different interpretation from that of annual data, it is of interest to report that Harvey and Jaeger (1991, 20) obtain cycle periods of 22 (13) periods for the US (Austria).

These results suggest a model with stochastic origins stemming largely from the trend. The ability of the estimated model to fit the GNP data is indicated by the graph (Figure 2) of fitted and actual observations. The fit is good although the model picks the major turning points with a one-period lag, reflecting the recursive nature of the changing trend.¹⁶

This result illustrates that a univariate business cycle can be represented by a model which includes a cycle as well as a stochastic trend, and without positing exogenous factors to explain the data. Models with deterministic trends plus a stationary

¹⁴ The model specification tests for heteroskedasticity, serial correlation and normality were passed by the model at any reasonable significance level. The details of these tests are available from the authors upon request.

¹⁵ Harvey and Jaeger (1991, 20) obtain cycle periods of 22 (13) periods for the US (Austria) using quarterly data. These data may yield fundamentally different cycles from those of annual data.

¹⁶ Such a lag is not peculiar to this structural time series model (see for example Kim (1988; 73)).

The Stochastic Trend plus Cycle Model

FIGURE 2

disturbance term may therefore be misspecified. Those which, in addition, search for break points may be trying to provide an alternative representation to that of a stochastic trend, but they ignore the presence of a cycle. While neither approach makes explicit use of economic theory or direct representation of economic structure the trend plus cycle approach offers a simple, plausible way to describe GNP data which is in accord with the longstanding interest of economists in business cycles (Kim 1988).

Conclusion

Our analysis strongly indicates that the IS representation of Canadian GNP and investment data as stationary with trend breaks in 1896, 1914 and 1939 is not unique: a large number of alternative theories of Canadian economic growth provide equally powerful explanations of the data. In addition, we have provided further tangible evidence that concerns about the application of unit root econometrics to finite data series must be taken seriously. Most importantly, we have shown that the trend in Canadian economic growth may plausibly be represented as stochastic rather than deterministic. If the correct representation of the trend is stochastic, then the Perron methodology may be interpreted as an attempt to mimic this trend, and, in the absence of a cycle, may be spurious.

Recent advances in the analysis of the problem of non-stationarity in macroeconomic time series have resulted in the development of a variety of plausible approaches to data representation and analysis which minimise the dangers of spurious regression results. But the combination of this technology with univariate models does not provide a rigorous basis for testing alternative economic hypotheses about the data generating mechanism or the sources and impact of exogenous shocks to the growth process for the period over which we have reliable macroeconomic data. The results in this paper confirm that tests for unit roots in univariate models have very limited ability to distinguish between the economically interesting alternative hypotheses about the long-run growth of the Canadian economy.

Appendix

The Impact of Sample Selection on Test Statistics

(a) Canadian Real GNP 1870 - 1985: $k = 3$

<u>Model Breaks</u>	<u>Test Statistic for Sample of Data</u>			
	<u>1875 - 1975</u>	<u>1880 - 1975</u>	<u>1875 - 1985</u>	<u>1880 - 1985</u>
1896 1914 1939	- 7.28*	- 7.03*	- 6.62*	- 6.38*
1929	- 5.31*	- 5.04*	- 5.13*	- 4.88*
1896 1929	- 5.70*	- 5.56*	- 5.43*	- 5.30*
1929 1949	- 5.17*	- 4.88*	- 5.18*	- 4.90*
1929 1973	- 5.21*	- 4.94*	- 5.49*	- 5.22*
No Break	- 2.75	- 2.56	- 3.01	- 2.78

(b) Canadian Real Gross Fixed Capital Formation 1870 - 1985: $k = 1$

<u>Model Breaks</u>	<u>Test Statistic for Sample of Data</u>			
	<u>1875 - 1975</u>	<u>1880 - 1975</u>	<u>1875 - 1985</u>	<u>1880 - 1985</u>
1896 1914 1939	- 5.62*	- 5.33*	- 5.17*	- 4.90
1929	- 4.98*	- 4.79*	- 4.69*	- 4.51*
1896 1929	- 5.75*	- 5.55*	- 5.35*	- 5.16*
1929 1949	- 4.57	- 4.37	- 4.73	- 4.53
1929 1973	- 4.93*	- 4.75	- 5.19*	- 5.01*
No Break	- 3.03	- 2.86	- 3.24	- 3.06

Notes:

- * - Significant at 5%.

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