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THE NEW ZEALAND BUSINESS CYCLE

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Our paper is in the spirit of Rex Bergstrom's interests and research in cyclical growth models and his meticulous attention to underlying data series. We develop a new quarterly real GDP series for post–World War II New Zealand, derive a new "benchmark" set of classical business cycle turning points, and establish non-parametric classical cycle characteristics. Markov-switching models, estimated by Gibbs-sampling methods, are used to derive mean growth rate and volatility regimes and to add to existing knowledge. The resulting properties, involving cycle asymmetries, volatility, diversity and duration dependence, and differing mean growth rate and volatility regimes, can be used to underpin a next generation of cyclical growth models for New Zealand, in the Bergstrom tradition.

1. INTRODUCTION

An enduring hallmark of Rex Bergstrom's scholarship was his pursuit of excellence in specifying models grounded in relevant economic theory, applying innovative econometric methodology, and utilizing meticulously assembled economic data (e.g., Phillips, 2006, p. 4). In the years to the late 1950s, Rex's empirical applications involved the New Zealand economy (e.g., Bergstrom, 1955); for much of the 1960s (e.g., Bergstrom, 1962, 1966, 1967) his focus was on developing models that could better capture an economy's cyclical growth processes. In turn, these models provided the foundations for his work over the past 30 years on increasingly sophisticated continuous-time models of the U.K. economy (Bergstrom and Wymer, 1976; Bergstrom and Nowman, 2006).

This paper is not in the Bergstrom modeling tradition of estimation of a continuous-time model with strong economic theoretic foundations; rather, it is in the spirit of his interests and research in cyclical growth models and his meticulous attention to underlying data series. In Section 2, we report the development of a new quarterly real GDP series for post–World War II (WWII) New Zealand.

We acknowledge stimulating comments from three referees, and have benefited considerably from Adrian Pagan's incisive comments on an earlier draft. James Tremewan provided professional programming and research assistance, funded by a research grant from VUW's School of Economics and Finance, and Brian Easton provided very helpful insights on key data periods. We also acknowledge helpful comments from presentations to a joint CAMA/RSSS Workshop at the ANU, the May 2006 A.R. Bergstrom Memorial Conference at the University of Essex, the Reserve Bank of New Zealand, and the August 2006 Meeting of the New Zealand Econometrics Study Group. Address correspondence to Viv B. Hall and C. John McDermott, School of Economics and Finance, Victoria University of Wellington, P O Box 600 Wellington, New Zealand; email: viv.hall@vuw.ac.nz, john.mcdermott@vuw.ac.nz.

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A new "benchmark" set of classical business cycle turning points, and corresponding nonparametric cycle characteristics are presented in Section 3. Results from two tests for duration dependence are reported in Section 4. In Section 5, Markov-switching models estimated by Gibbs-sampling methods (Kim and Nelson, 1999) are used to derive mean growth rate and volatility regimes, and to add to existing knowledge. The properties established in Sections 3, 4, and 5, involving cycle asymmetries, volatility, diversity, duration dependence, and mean growth rate and volatility regimes, can be used to underpin a next generation of cyclical growth models for New Zealand, in the Bergstrom tradition.[1] Conclusions are drawn in Section 6.

2. DATA

At present, there are no official quarterly real GDP estimates for New Zealand for the period prior to 1977. The current official chain-linked series goes back only to 1987, a span of time that includes only two completed classical business cycles. There is a non–chain-linked series published by Statistics New Zealand (SNZ) that covers the period 1977 to 1987, but including these additional observations can still provide only four completed cycles. This is clearly an insufficient number for robust business cycle analysis. Construction of our new quarterly real GDP series for the post-WWII sample period, 1947q2 to 2006q2, has therefore involved linking the recent official quarterly observations to temporally disaggregated observations for an earlier time period.[2] The linked series is scaled to a 1995/96 base.

Temporal disaggregation is commonly resorted to when official statistical agencies are unable to provide data at a required frequency, and it is based on techniques that use indicator series that are available at a higher frequency and are related closely to the series of interest. The methods most commonly cited are those of Chow and Lin (1971), Fernández (1981), and Litterman (1983), and the one most often used is the relatively simple Chow-Lin regression method, dependent on a single autoregression parameter.[3] The results presented below come from the series that includes observations estimated by the Chow-Lin method.

Official data have been used where available. We use SNZ's System of National Accounts quarterly series SNB, in 1991/92 prices, for the period 1977q2 to 1987q1. Their current quarterly series SNC, in 1995/96 prices, is used for 1987q2 to 2006q2. Annual time series observations for the period 1947 to 1977 were obtained from SNZ's long-term data series webpage.[4] For 1947 to 1955, these observations are based on annual growth rates presented in Easton (1990), and for 1955 to 1977, the source is SNZ's annual SNB series (1991/92 base).

For our quarterly indicator series of aggregate economic activity, two diffusion indexes constructed by Haywood and Campbell (1976; HC) provide the best information available. They construct, for the period 1947q1 to 1974q4, a weighted classical cycle index and a weighted amplitude adjusted index from 63 time-series indicators. The weights are based on each series' relative economic significance, with consideration also being given to the importance of the sector to which each series belongs. We extended their series to 1977q4, using Easton's (1997) weighted static deviation cycle index and a trend growth rate of 2.3% per annum, consistent with the Haywood and Campbell indexes. All results presented below are based on the slightly smoother weighted classical cycle index.[5] The Chow-Lin regression was estimated over the period 1947q2 to 1979q1, rather than just to 1977q2. This was to avoid a potentially awkward discontinuity associated with joining the Chow-Lin estimates at 1977. That joining point was potentially problematic for two reasons: firstly, because SNZ's quarterly and annual series do not match for the 1977 year; and secondly, because the SNZ growth estimates for 1977 remain in dispute due to underlying data discontinuities.[6] Hence, the results presented below include temporally disaggregated observations estimated by the Chow-Lin method over the sample period 1947q2 to 1979q1.[7] The full sample series in logarithmic levels form and its annual percentage growth rates are shown in Figure 1.

To what extent do we believe this new series is credible and useful? Ultimately, this will depend on the extent to which it is used, but in Hall and McDermott (2007a, s. 5), we have evaluated the series' statistical properties and tested for structural breaks. Unit root tests confirm that, for this span of data of nearly 60 years, our series should provide an informative long-term trend.[8] Stylized statistical facts for four subperiods, corresponding closely with the sets of observations from different data sources or methods, are consistent with the view that the subperiod 1947q2 to 1954q1 was a time of unusual fluctuations in economic activity, associated with exceptional post-WWII events.[9] We therefore recommend that considerable caution should be exercised if observations from the beginning of the full sample are to be used. In a business cycle context, this means that for most statistical applications, but not necessarily for classical business cycle dating, the sample should be restricted to the period from 1954q2.

We have also assessed whether our new series might suffer from unacceptably large measurement error, due to different construction methods and a mix of official and nonofficial data sources.[10] We would not have expected material differences in the series' statistical properties at this aggregate level, due to splicing the chain-linked and non–chain-linked data. It was also our prior view that the 63 time series used for the HC diffusion index were sufficiently wide-ranging in coverage. However, the use of temporal disaggregation methodology could have led those observations exhibiting properties that are different from observations derived using official quarterly series methodology. Different properties might also have been associated with exceptional economic events, such as those in the immediate post-WWII period and those prior to and around New Zealand's major economic reforms. Accordingly, we tested for significant structural breaks. There is a significant structural break in the GDP growth rate at 1991q1, and in its variance at 1952q3 (Hall and McDermott, 2007a, Table 10). Both breaks coincide with material changes in economic activity, rather than with splicing chain-linked and non–chain-linked data or splicing temporally disaggregated and

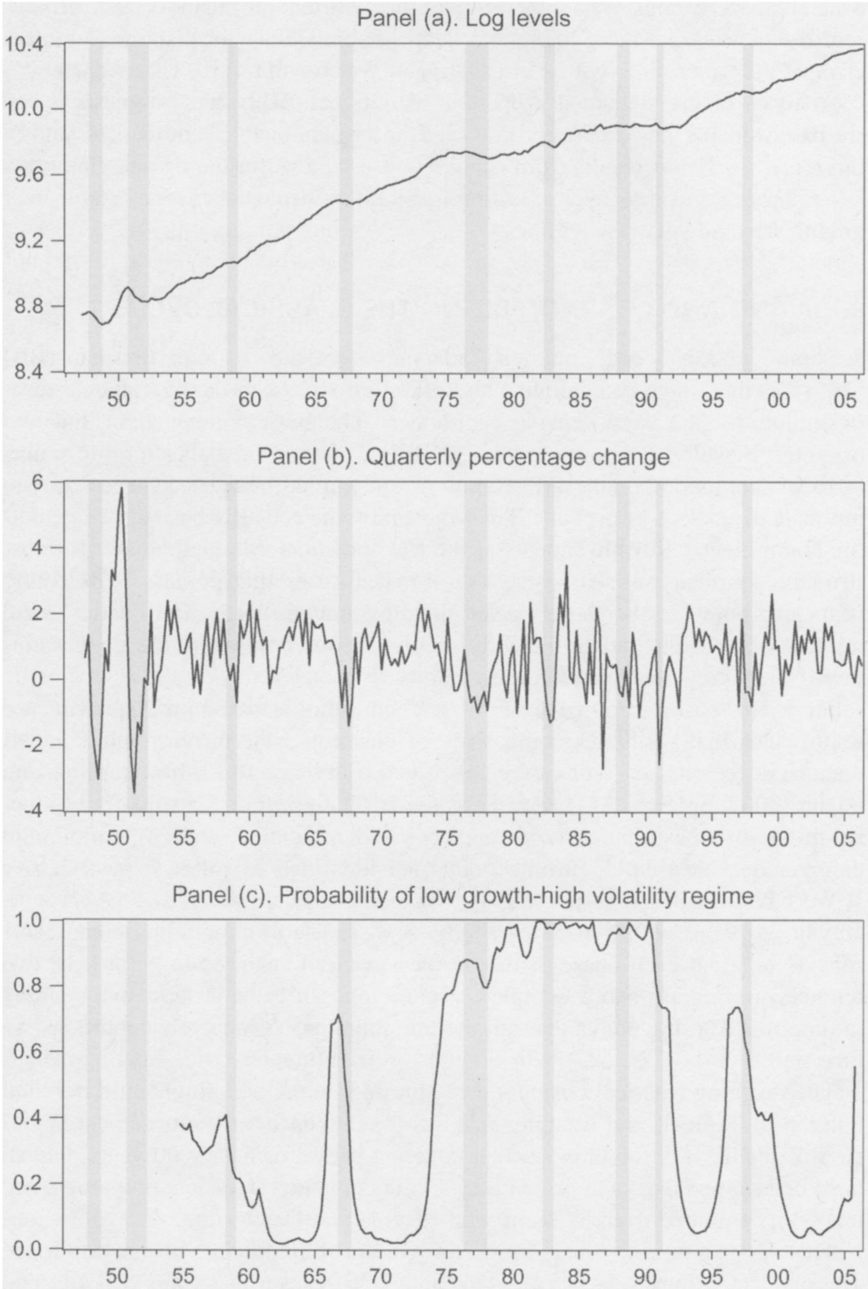

FIGURE 1. New Zealand real GDP, 1947q2–2006q2 Classical contractions indicated by shading.

official quarterly data. We are therefore of the view that the business cycle properties of our series are more likely to reflect economic behavior than measurement error of the type found by Romer (1986) and Watson (1994) for U.S. data.

Analysis of the statistical properties of our real GDP series suggests it can provide valuable new quarterly real GDP information. In Sections 3, 4, and 5, therefore, we report results from using its observations for dating and characterizing classical business cycles, testing for duration dependence, and establishing growth rate and volatility regimes.

3. DATING AND CHARACTERIZING THE CLASSICAL CYCLE

For more than a decade, quarterly adaptations of the Bry and Boschan (BB) (1971) method have been applied successfully to assist in dating classical turning points for the New Zealand economy.[11] The BB computer algorithm was originally developed to automate the NBER's method of dating turning points in individual monthly data series. More recently, it has been used successfully to replicate as closely as possible dates chosen by the NBER's business cycle dating committee.[12] Key advantages of the BB nonparametric method are its transparency, simplicity, and robustness to the data generating process.[13] Its dating of turning points is also largely determined by movements around a series' local minima or maxima, and so the addition of new observations to the times series rarely alters previously dated turning points.[14]

For these reasons, and because the BB algorithm is based on a standardized set of rules that facilitates comparison of business cycle turning points across countries, regions, or types of economic activity, we use what Harding and Pagan (2002, pp. 369, 371) refer to as the BBQ algorithm. This quarterly algorithm has two basic parts: (i) turning point identification, and (ii) a minimum phase and cycle rule.[15] Turning points are identified as follows: peak at $t = \{(\Delta_2 y_t, \Delta y_t) > 0, (\Delta y_{t+1}, \Delta_2 y_{t+2}) < 0\}$ and trough at $t = \{(\Delta_2 y_t, \Delta y_t) < 0, (\Delta y_{t+1}, \Delta_2 y_{t+2}) > 0\}$, where $\Delta_2 y_t = y_t - y_{t-2}$. The minimum phase and cycle rule is such that each phase of the business cycle is required to be at least two quarters in duration and a complete cycle is chosen to be at least five quarters in duration. Turning points that fail the minimum phase and cycle conditions are censored.

The resulting classical business cycle turning points are presented in the final column of Table 1, and we offer them as a new benchmark set for post-WWII New Zealand. It is the only set that covers a period of nearly 60 years, has all been determined from a series with clearly documented statistical properties, and has been computed from the same well-regarded BBQ algorithm.

The classical turning points for shorter periods, found in previous research, are presented in columns 2, 3, and 4 of Table 1. Haywood and Campbell's (1976, Table 2) dates were derived judgmentally from their two diffusion indexes. The Kim, Buckle, and Hall (1995, pp. 163–164) benchmark dates combined results from three different sources. Hall and McDermott's (2007b) dates are from the

TABLE 1. Peaks and troughs for New Zealand post-WWII classical business cycles

Peak/ trough	Haywood and Campbell (1976)	Kim, Buckle, and Hall (1995)**	Hall and McDermott (2007b)***	New 'benchmark' turning points****
P				**1947q4**
T				**1948q4**
P				**1950q4**
T				**1952q2**
P	1958q1*			**1958q2**
T	**1959q1***			**1959q1**
P	1961q2*			–
T	1962q1*			–
P	1967q2	1966q3		**1966q4**
T	**1967q4**	1968q3		**1967q4**
P		1970q1		–
T		1970q4		–
P		1974q3		–
T		1975q2		–
P		1976q4		**1976q2**
T		**1978q1**	1977q4	**1978q1**
P		**1982q2**	**1982q2**	**1982q2**
T		**1983q1**	**1983q1**	**1983q1**
P		1986q3	1986q3	–
T		–	–	–
P		–	–	**1987q4**
T		–	**1988q4**	**1988q4**
P		–	1989q2	–
T		–	1990q1	–
P		–	**1990q4**	**1990q4**
T		**1991q2**	**1991q2**	**1991q2**
P		–	**1997q2**	**1997q2**
T			**1998q1**	**1998q1**

Notes: Bold dates represent preferred peak/trough dates. Differences in KBH, HMcD (2007b), and new benchmark turning points from the mid-1980s reflect successive data revisions by SNZ, which since 1987q2 have been for chain-weighted data.

*Not conclusive evidence of a classical recession, according to Haywood and Campbell (1976, Note to Table 2). These are judgmental turning points, from their weighted Classical cycle indexes.

**Center for International Business Cycle Research (1992) judgmental dates, 1966q3 and 1968q3; from 1970q1 to 1976q4, BBQ method, expenditure-based real GDP; from 1978q1, BBQ method, production-based real GDP.

***BBQ method, production-based real GDP.

****BBQ method, new quarterly linked series, using temporally disaggregated observations generated from Chow-Lin regression model, Hall and McDermott (2007a).

BBQ algorithm, run on linked official non–chain-weighted and chain-weighted production-based real GDP series that have been subject to further data revisions, and do not extend further back than the trough at 1977q4.

Our benchmark results identify nine classical contractions that are considered important episodes in New Zealand's economic history. The more recent and commonly known contractions are those of the early 1980s, the early 1990s, and the 1997–98 period associated with the Asian financial crisis and the summer droughts. Earlier in the period, the BBQ algorithm identifies a number of contractions that occurred around the time of exchange rate crises that were experienced in 1957 to 1958 and 1966 to 1967 (Hawke, 1985, p. 174). Previous research has identified other exchange rate crisis episodes around 1955 and 1961 as contractions, but while those episodes are clearly growth slowdowns, they are not classical contractions. This conclusion is consistent with conclusions drawn by Haywood and Campbell (1976). It is also consistent with the history recorded by King (2004, p. 431), who identified particular episodes in the 1950s as important, since in his view, "Apart from the temporary drop in overseas reserves which triggered the Labour Government's 'Black Budget' in 1958, and its highly unpopular reimposition of severe import controls, the 1950s was generally a prosperous decade – especially after the Korean War created a sales boom for New Zealand wool."

Figure 1 summarizes the turning points and phases of the New Zealand business cycle. The shaded areas represent the contraction phases, with peaks and troughs at their left- and right-hand edges respectively.

Cycle characteristics for duration, amplitude, cumulated gains or losses, and excess gains or losses are presented in Table 2. They cover individual expansion and contraction phases and their average values. Together with the coefficients of variation (CV), these descriptive statistics enable us to form summary judgments on the range of asymmetries and the degrees of volatility associated with the New Zealand cycle.

The average *duration* for expansion phases has been over five years (20.6 quarters), considerably longer than the average contraction phase of one year (4.0 quarters). New Zealand's average expansion phase, for not dissimilar periods,[16] is somewhat longer than those reported by Harding and Pagan (2002, p. 372) for the United States (17.8 quarters) and the United Kingdom (16.1 quarters), but identical to Australia's (20.6 quarters). The average contraction phase for New Zealand is somewhat longer than those of the other three countries (3, 3.75, and 3.3 quarters, respectively). The CV of 0.47, associated with the average expansion duration, reflects noticeably different durations for the individual phases, and is somewhat lower than the U.S. experience (0.60).[17] More striking is the influence of two relatively long six- and seven-quarter contraction phases during the first half of the sample, which contribute to the CV of 0.4, 18% greater than the figure of 0.34 for the United States.

The mean *amplitude* of New Zealand's expansion phases is 25.5%, above that of the U.K. (14.5%) and the U.S. (20.2%) but close to the amplitude for

TABLE 2. Classical cycle characteristics for New Zealand real GDP, 1947q2 to 2006q2

Phase number	Turning point dates		Duration		Amplitude		Cumulated gain/loss		Excess gain/loss	
	Peak	Trough	E	C	E	C	E	C	E	C
1	1947q4	1948q4		4		−8.0		−15.6		−2.9
2	1950q4	1952q2	8	6	23.0	−8.9	78.9	−37.2	−14.2	39.5
3	1958q2	1959q1	24	3	24.0	−0.2	283.6	−0.0	−1.5	−95.9
4	1966q4	1967q4	31	4	38.5	−2.5	609.3	−4.3	2.1	−13.7
5	1976q2	1978q1	34	7	31.8	−4.2	583.2	−12.8	8.0	−13.1
6	1982q2	1983q1	17	3	10.2	−3.2	68.8	−4.5	−20.5	−8.1
7	1987q4	1988q4	19	4	13.4	−1.2	178.1	−2.1	40.1	−13.4
8	1990q4	1991q2	8	2	2.5	−3.3	10.0	−4.2	−1.0	27.9
9	1997q2	1998q1	24	3	22.9	−1.5	258.2	−1.8	−6.1	−19.0
Average			20.63	4.00	25.5	−3.9	258.8	−8.2	0.8	−11.0
CV			0.47	0.40	0.46	−0.77				
Duration dependence tests†										
Quarterly data (1947–2006)										
Brain-Shapiro			0.218	0.268						
OTP SB			0.074	0.015						
Annual data (1860–2006)										
Brain-Shapiro			0.359	–						
OTP SB			0.081	–						

Note: E denotes expansion phase; C is contraction phase; durations are in quarters; amplitudes are percentages; cumulated gains or losses are percentages of GDP in first quarter of the phase; excess area percentages show how much extra output is gained or lost relative to the economy growing at a constant rate; CV is the coefficient of variation.
† denotes p-values.

Australia (24.7%). The corresponding CV of 0.46 is not dissimilar to that for the U.S. (0.56). The average contraction-phase amplitude of −3.9% is below those of Australia (−2.2%), the U.S. (−2.5%), and the U.K. (−2.5%). However, it is striking that for the contraction-phase amplitude, New Zealand's CV of −0.77% is greater in absolute terms than the CV of −0.52% for the United States.

These results provide clear evidence of *asymmetry* for the average duration and amplitude of the New Zealand business cycle, considerable evidence of *individual cycle diversity*, and preliminary evidence of greater than "standard" *volatility* of cycles, especially over contraction phases. The key difference of the New Zealand business cycle relative to those of Australia, the United States, and the United Kingdom is the longer duration and deeper amplitude of contractions.

But what of cycle "shape," which combines knowledge of durations and amplitudes? Two illustrative measures offered by Harding and Pagan (2002) are "triangle area" *cumulated gains or losses* in real GDP relative to no growth, and *excess gains or losses* relative to a constant rate of growth.[18] These measures further confirm considerable diversity across cycle phases. The average cumulated gain during expansions is 259% for New Zealand, a measure straddling the 196% for the U.K., 256% for the U.S., and 320% for Australia. New Zealand's average cumulated losses during contractions of 8.2% have been somewhat greater than those sustained by the others (4.1, 6.1, and 4.0%, respectively), with its largest losses accumulated during two of the early period contractions. The average excess loss of 11% is above that for the U.S. (6%) and the excess gain of 0.8% is well below that of the U.S. (9%).

4. TESTING FOR DURATION DEPENDENCE

Classifying economic fluctuations into expansions and contractions naturally leads to thinking about the length of time until a given phase of the cycle comes to an end and whether the time already spent in a phase influences the probability of that phase ending. We use two tests for duration dependence: the Brain-Shapiro (1983) test as used by Diebold and Rudebusch (1990); and the state-based (SB) test of Ohn, Taylor, and Pagan (2004; OTP). Their relative merits differ. The Brain-Shapiro test is probably more widely recognized, very simple to compute, and easily resolved from standard t-tables; but the number of observations in its regression equations is almost always constrained by a limited number of business cycle phases. The OTP-SB test benefits from a considerably greater number of state variable observations,[19] but in this case standard t-tables cannot be reliably used and appropriate p-values need to be simulated.

The null hypothesis of both tests is that the probability of exiting a phase is independent of the length of time the economy has already been in that phase, i.e., no duration dependence.

The Brain-Shapiro test is based on the regression $w_i = \alpha + \beta i + e_i, i = 2, \ldots, N$, where $w_i = (N - i+1)\ (x_i - x_{i-1})$, N is the number of phases, and x_i is the i^{th} ordered duration. The hypothesis of no duration dependence is given by $\beta = 0$.

The OTP-SB test is based on the regression $S_t = \alpha + \beta d_{t-1} + e_t$, where S_t is the state variable that equals one in expansions and zero in contractions, and d_t is the number of consecutive quarters spent in an expansion (less one) up to time t. Unity is subtracted from the duration to account for the minimum phase censoring rule. The regression is run only on half-cycle data; for example, when considering duration dependence for expansions, contraction periods are excluded from the regression. The hypothesis of no duration dependence is again given by β=0. For the appropriate p-values we use a simulation size of 10,000 as in OTP.

Density estimates of duration data or simple plots of the hazard functions are suggestive of some positive duration dependence (i.e., the probability of an expansion or contraction phase of the business cycle increasing the longer the economy is in a given phase). However, given the relatively small number of business cycles in our sample, we need to be cautious interpreting such plots, so we use the formal test of duration dependence to examine whether this suggestion is spurious.

For expansions, the Brain-Shapiro and OTP-SB p-values are 0.218 and 0.074, respectively. The corresponding p-values for contraction phases are 0.268 and 0.015. For expansions, therefore, we have no evidence to reject the null hypothesis of no duration dependence.[20] However, for contractions the evidence is less clear cut.

In this context, with only eight expansion phases and nine contraction phases in our sample, the power of the formal tests used is likely to be relatively low. So, to supplement our evidence, we consider the duration of economic expansions from 1860 to 2006 based on the long-term *Statistics New Zealand* data series referred to above.[21] There are 21 completed expansions for this 147-year period, yielding Brain-Shapiro and OTP-SB p-values of 0.359 and 0.081, respectively. There appears to be even less evidence of duration dependence for the longer sample period.

In other words, New Zealand business cycle expansion paths are likely not to have died of old age, but rather to have been terminated by particular events. This is a particularly important property that should be reflected in the specification of models of the New Zealand business cycle. There is a steadily accumulating body of research evidence on potential candidates for shocks capable of triggering or terminating business cycle phases, and somewhat greater uncertainty on key events that might have been conditioning business cycle transmission mechanisms. For example, candidate events that have been credibly established by previous research as shocks to classical and/or growth cycles include international price and output shocks (Wells and Evans, 1985; Buckle, Kim, Kirkham, McLellan, and Sharma, 2007; Hall and McDermott, 2007b), unusually dry climatic conditions (Buckle et al., 2007; Hall and McDermott, 2007b), various domestic and international financial sector impulses (Buckle, Kim, and McLellan, 2003), and discretionary fiscal policy impulses (Claus, Gill, Lee, and McLellan, 2006).[22] Candidate events or factors, potentially conditioning cycle dynamics, about which there is considerably less certainty, would include the degrees of responsiveness and structural changes associated with New Zealand's major policy reforms of the mid- to late-1980s and early 1990s, excessive movements in asset prices (especially housing), the efficacy of monetary policy, and material exchange rate volatility.

5. REGIME CHANGES IN THE GROWTH AND VOLATILITY OF OUTPUT

The results presented in Section 3 provide considerable evidence of individual classical cycle diversity, and preliminary evidence of greater than standard volatility. But it is also important to establish whether New Zealand's growth and volatility movements exhibit considerable diversity, and in particular whether future cyclical growth models should be specified to capture different growth and volatility regimes.

Three pieces of evidence suggest it would be useful to examine the stochastic behavior of economic fluctuations through some form of autoregressive model exhibiting regime change to growth rate and volatility.[23] Firstly, visual inspection of the slopes of the log levels of real GDP in Figure 1, Panel (a), and the considerable changes in their quarterly percentage growth rates in Panel (b), suggest the possibility of regime changes for both variables. Secondly, the different growth rate and volatility figures presented for four illustrative subperiods in Panel (a) of Table 3 also point to different growth and volatility rates being a salient feature of our new data series. The first period, 1947q2 to 1954q1, termed by us the "post-WWII adjustment" period, exhibits a modest growth rate and unusually high volatility; period two, 1954q2 to 1976q4, which we refer to as the "golden days" period, has a high growth rate and low volatility; the third period, the "terms of trade shock and reform" period, 1977q1 to 1991q4, is one of low growth and reasonably high volatility; and the fourth and most recent period (1992q1 to 2006q2) of potentially "new golden days," like the second subperiod, is also one of high growth and low volatility. Thirdly, Buckle, Haugh, and Thomson (2004; BHT) have shown that, for the period 1978q1 to 2003q2, a 3-2 Markov-switching model (MSM) can provide both a good representation of the differing mean growth rates and volatilities of their series, and economically meaningful regime classifications.

The Markov-switching models investigated for our considerably longer sample period of more than 50 years of quarterly observations were informed by the above illustrative subperiod growth rates and volatilities, by BHT's most successful models being 3-2 and 2-2,[24] and by the 2-1 model having been successfully applied to the analysis of the U.S. business cycle. Our estimation strategy is based on the Bayesian Gibbs-sampling approach,[25] and as explained below, our preferred results come from a 2-2 model. The MSM estimation and testing methodology that follows is therefore presented in a 2-2 model Gibbs-sampling context.

The log of real GDP growth (denoted y_t) is assumed to follow the two-state MSM process $\Delta y_t - \mu_{S_t} = \sum_1^q \phi_i(\Delta y_{t-i} - \mu_{S_{t-i}}) + u_t$, where $u_t \sim N(0, \sigma_{S_t}^2)$, $\mu_{S_t} = \mu_i$ if $S_t = i$ $(i = 1,2)$, $\sigma_{S_t} = \sigma_i$ if $S_t = i$ $(i = 1,2)$, $S_t = 1$ if the economy is in a low growth–high variance state at date t, and $S_t = 2$ if it is in a high growth–low variance state at date t. A sequential testing procedure was used to determine the order of the AR process, resulting in $q = 2$ for the 2-2 model and $q = 0$ for the 2-1 model. The maximum number of lags considered was 4.

We assume that the transition from different states follows a first-order Markov process where the transition probabilities are given by $p_{ij} = \Pr(S_t = j | S_{t-1} = i)$, subject to the constraints $0 \leq p_{ij} \leq 1$, $p_{11} + p_{12} = 1$, and $p_{21} + p_{22} = 1$.

For Bayesian inference of the model, we need marginal posterior distributions for the following: $\mu = (\mu_1 \mu_2)'$; $\phi = (\phi_1 \phi_2)'$; $\sigma = [\sigma_1 \sigma_2]'$; $S_T = [S_1, \ldots, S_T]'$; and $p = [p_{11} p_{22}]'$. As outlined by Kim and Nelson (1999), these marginal posterior distributions may be obtained from the joint posterior distribution $p(\mu, \phi, \sigma, S_T, p, | Y_T)$, where $Y_T = [\Delta y_1, \ldots, \Delta y_T]'$. Gibbs sampling can be used to obtain the marginal posterior distributions of interest. This is done by successively sampling from the full conditional densities. Kim and Nelson (1999) outline the sampling procedure as iterating the following five steps:

1. Generate μ, conditional on ϕ, σ, S_T and Y_T
2. Generate ϕ, conditional on μ, σ, S_T and Y_T
3. Generate σ, conditional on μ, ϕ, S_T and Y_T
4. Generate S_T, conditional on μ, ϕ, σ, p and Y_T
5. Generate p, conditional on S_T.

The prior distributions, consistent with subperiod quarterly growth rates, are: $\mu_1 \sim N(0, 0.04)$, $\mu_2 \sim N(1, 0.04)$, $\phi_1 \sim N(0.4, 0.04)$, $\phi_2 \sim N(0.2, 0.04)$, $1/\sigma_j^2 \sim Gamma(1, 1)$, and $p_{jj} \sim Beta(9, 1)$, where *Beta*(. , .) and *Gamma*(. , .) refer to the Beta distribution and Gamma distribution, respectively.

Before discussing our estimation results, we note the diagnostics used to satisfy ourselves that the Markov chain has converged. The first test we use is the Geweke (1992) statistic, which aims to monitor convergence of each scalar estimand and can be useful in determining the appropriate *burn-in size*. We guessed the initial burn-in size to be 1,000 simulations. Following the suggestion of Gelman, Carlin, Stern, and Rubin (2004), we then tested whether the initial burn-in size was appropriate. If not, the burn-in size was doubled. This procedure continued until the burn-in size was sufficient according to the formal diagnostics. The Geweke (1992) statistic is defined as

$$z = \frac{\bar{\theta}_a - \bar{\theta}_b}{\sqrt{V(\bar{\theta}_a) + V(\bar{\theta}_b)}}, \quad \text{where} \quad \bar{\theta}_a = \frac{1}{n_a} \sum_{i=N+1}^{N+n_a} \theta_i \quad \text{and} \quad \bar{\theta}_b = \frac{1}{n_b} \sum_{i=N+n-n_b+1}^{N+n} \theta_i$$

for a chain run $N + n$ steps with $n > n_a + n_b$. The variances are estimated using the Newey-West estimator. The distribution of z is approximated as a standard normal if the chain has converged. Computing z for a range of values N provides a guide for the required burn-in. In practice, a large range of N can be computed very quickly, but to save space we show results in Table 3 only for the final case where N = 3,000 and $n_a = n_b = 500$.

TABLE 3. Regime changes in the growth and volatility of output

Panel (a). Real GDP growth rates and volatility, for selected subperiods

	Annual average growth rate (%)	Growth rate regime	Volatility (standard deviation of growth rate)	Volatility regime
1947q2 – 1954q1	2.2	Medium	.46	Very high
1954q2 – 1976q4	3.7	High	.16	Low
1977q1 – 1991q4	1.1	Low	.23	High/medium
1992q1 – 2006q2	3.3	High	.15	Low

Panel (b). Gibbs-sampling estimates and diagnostic statistics for Markov-switching models, 1954q2 to 2006q2

	2-2 Model low growth–high volatility, high growth–low volatility				2-1 Model low growth–common volatility, high growth–common volatility			
Parameter	Estimate	Standard error	Geweke	Gelman-Rubin	Estimate	Standard error	Geweke	Gelman-Rubin
μ_1	0.337	0.286	−0.034	1.00167	−0.023	0.032	0.020	1.00022
μ_2	0.992	0.291***	−0.027	1.00034	0.597	0.149***	−0.042	1.00020
ϕ_1	0.180	0.124	0.005	1.00049				
ϕ_2	0.190	0.109*	−0.018	1.00034				
p_{11}	0.954	0.112***	0.085	1.00096	0.832	0.134***	−0.047	1.00024
p_{22}	0.949	0.103***	0.106	1.00072	0.898	0.113***	−0.101	1.00028
σ_1	1.253	0.697*	−0.011	1.00403	1.153	0.306***	0.032	1.00021
σ_2	0.413	0.228*	0.066	1.01890				

Note: *** (*) denotes t-statistic significantly different from zero at 1% (10%) level. The standard errors are Newey-West based. The Geweke (1992) and Gelman and Rubin (1992) tests are defined in the text.

The second test we used was the Gelman and Rubin (1992) test, which is designed to monitor the *convergence of each scalar estimand.* Gelman and Rubin (1992) propose simulating m parallel chains, each of length n (after excluding the burn-in period of 2,000 replications). For each scalar estimand θ, denote the simulation draws as θ_{ij} $(i = 1, \ldots, n; j = 1, \ldots, m)$, and compute the between-chain variance as

$$B = \frac{n}{m-1} \sum_{j=1}^{m} \left(\bar{\theta}_{\cdot j} - \bar{\theta}_{\cdot\cdot}\right)^2, \quad \text{where} \quad \bar{\theta}_{\cdot j} = \frac{1}{n} \sum_{i=1}^{n} \theta_{ij}, \qquad \bar{\theta}_{\cdot\cdot} = \frac{1}{m} \sum_{j=1}^{m} \bar{\theta}_{\cdot j},$$

and the within-chain variance as

$$W = \frac{1}{m(n-1)} \sum_{j=1}^{m} \sum_{i=1}^{n} \left(\theta_{ij} - \bar{\theta}_{\cdot j}\right)^2.$$

An estimate of the total variance is given by

$$V = \frac{n-1}{n} W + \frac{1}{n} B.$$

Gelman et al. (2004) suggest using $R = \sqrt{V/W}$ as a measure of convergence and accepting convergence if $R < 1.1$, although they note that the exact criteria depend on the problem under consideration. For our purposes their recommendation is suitable. In our simulation exercise we run 30 parallel chains (m = 30), each of length 10,000. The diagnostic statistics, presented in Panel (b) of Table 3, suggest the chain has converged.

Having satisfied ourselves as to the burn-in period and convergence of the chain, we evaluate the Bayesian posterior estimates for the 2-2 and 2-1 regime switching models, presented in Panel (b) of Table 3, and the plotted, smoothed probabilities $\Pr(S_t = j \mid \Delta y_1, \Delta y_2, \ldots, \Delta y_T; \hat{\alpha})$, presented in Figure 1's panel (c). The 2-2 model has two growth rates and two volatilities, with low growth–high volatility and high growth–low volatility regimes; the 2-1 model has two growth rates and a common variance, with low growth–common volatility and high growth–common volatility regimes.

The start date for results presented in Table 3 is 1954q2. This is because, as explained in Section 2 above, the subperiod 1947q2 to 1954q1 was a time of unusual fluctuations in economic activity, associated with exceptional post-WWII events. We also recommended in Section 2 that, for most statistical applications, the sample period should be restricted to the period from 1954q2. This is consistent with research by Easton (1997), who concluded that most countries' post-WWII business cycle took about five years to settle down to normal patterns, whereas New Zealand's took about 10 years. Our initial judgment was confirmed, when the full-sample results for the 3-3 and 3-2 models, suggested as potentially most appropriate by Panel (a)'s subperiods, could not provide sufficiently credible explanations of the full-period's economic behavior.[26]

Our two-regime 2-2 model is preferred to the two-regime 2-1 model. This is firstly because its two growth rate estimates capture Panel (a)'s subperiod growth rates more satisfactorily. Secondly, as explained below in the context of Figure 1, Panel (c), the model with two volatilities leads to very credible capturing New Zealand's major low growth–high volatility period of 1977 to 1991, dominated by large terms of trade shocks and the significant policy reforms required to adjust to these shocks.

The empirical parameter estimates, presented in Table 3 for our preferred 2-2 model, reflect the fact that the draws from the Markov chain used in the Gibbs-sampling approach showed evidence of some serial correlation. The standard deviation for each parameter was therefore computed using the Newey-West variance estimator that is robust to heteroskedasticity and autocorrelation. The Newey-West standard deviations are higher than would be the case for estimates where no serial correlation is assumed, and are not as consistently low as those reported by BHT. Nevertheless, we feel our point estimates provide valuable indicative information on growth and volatility regimes, and they are not dissimilar to those from BHT's 2-2 and 3-2 models. For example, the mean growth rate for our high growth–low volatility regime is approximately 4%, around three times greater than the 1.4% for the low growth–high volatility regime. The comparable BHT 2-2 model growth rates are 4.4% and 1.8%; with their predominant 3-2 model rates being 4% and 0.9%. Our mean high and low volatilities are both significant only at the 10% level, but with standard deviations of 1.25 and 0.4, are not inconsistent with estimates from BHT's 2-2 and 3-2 models (1.15 and 0.5, and 1.03 and 0.4, respectively). Some differences should be expected, given that our longer sample period contains some additionally different behavior.

It is common to use smoothed probabilities of the type presented in Panel (c) of Figure 1 to identify economic recessions by using a rule that a recession (low growth regime) occurs if $\Pr[S_t=1/\Delta y_1, \ldots, \Delta y_t,] > 0.5$. For example, Chauvet and Piger (2003) show that the smoothed probabilities from 2-1 (Hamilton) models for U.S. data have continued to be successful in replicating NBER business cycle turning points. Harding and Pagan (2003a) warn that there is no guarantee that rules applied to such probabilities will in all cases be successful in identifying classical contraction phases, and it is clear from both the BHT and our MSM results for New Zealand data that this warning is appropriate.

Several important features of our low growth–high volatility, and high growth–low volatility smoothed probabilities are worth emphasizing, as these reinforce the importance of differentiating between classical contraction phases and low growth regimes.

For example, the smoothed probabilities of being in the *low growth–high volatility* regime remain consistently high (between 0.8 and 1.0) throughout the period 1977 to 1991, and do not separately identify the four classical contractions documented in Table 1, as indicated by shading in Figure 1. With somewhat lower MSM probability (around 0.7), though, the classical contractions of 1966q4 to 1967q4, and of 1997q2 to 1998q1, correspond closely with MSM low growth periods. The classical contraction of 1958q2 to 1959q1 may also be associated with low growth, though the smoothed probability is only 0.4.

With respect to our *high growth–low volatility* periods, the latter two of our four periods can be seen from Panel (c) to be basically consistent with BHT's post-economic reforms' periods of growth "nirvana" (from 1992q4 to 1996q4 and from 2001q2 till the end of their sample period in 2003q2). Earlier in this section, we termed this our new golden days period. The additional two high growth–low volatility periods identifiable from Panel (c) cover the late 1950s to the mid-1970s (our golden days period) and are interrupted briefly by the short 1966–67 low growth period.

6. CONCLUSIONS

The main contributions of this paper are, firstly, that we develop a new quarterly real GDP series for post-World War II New Zealand. Secondly, we use this to present a new, consistently derived set of benchmark classical business cycle turning points. These extend back to 1947 the quantitatively-derived turning points presented in Hall and McDermott (2007b), and supersede the previous benchmark set offered in Kim, Buckle, and Hall (1995). This enables us to utilize eight full (P-T-P) cycles, to establish classical business cycle properties, to test for the important cycle property of phase duration, and to conclude for expansion phases that there is no evidence of duration dependence. New Zealand business cycle expansions over this period are therefore likely not to have died of old age, but rather to have been terminated by particular events. Thirdly, we estimate our Markov-switching models by Gibbs sampling, instead of by the more commonly used classical maximum likelihood method. Fourthly, we extend back to the postwar pre-1977 period our knowledge of New Zealand's business cycle growth rate and volatility regimes.

Our sets of turning points and growth rate regimes also show that the New Zealand business cycle has asymmetries of duration, amplitude, cumulated gains or losses in real GDP, and excess gains or losses. There is considerable diversity across individual cycles and considerable volatility in durations and amplitudes.

Conclusions from our preferred 2-state Markov-switching model are, for the period after 1977, broadly consistent with those of Buckle, Haugh, and Thomson (2004), as our new golden days period corresponds with their periods of economic growth nirvana. However, in the first half of our sample, we additionally identify two golden days or nirvana periods, interrupted briefly by the short 1966q2 to 1967q2 low growth–high volatility period.

The diversity in individual cycles comes from disruptions to the typical pattern of the business cycle, following terms of trade shocks such as the 1970's oil shocks and the loss of a major export market when the United Kingdom joined the EEC, and the major economic reforms of the mid-1980s through the early 1990s. Results also point to a return, since the early 1990s, to a more rhythmic pattern of long expansions and short contractions.

The classical business cycle properties, and the growth rate and volatility regimes we establish, can be used to underpin a next generation of cyclical growth models for New Zealand, in the Bergstrom tradition.

NOTES

1. Bailey, Hall and Phillips (1987) report the theoretical development of a small nonlinear continuous-time model for New Zealand, in the Bergstrom tradition. Their prototype model of output, employment, capital formation, and inflation was designed to explain medium-term cyclical growth, combining neoclassical and New-Keynesian economic theories, and allowing explicitly for disequilibrium in the markets for goods and labor services.

2. Further detail on our sources and methodology, and on the statistical properties of this series, is available in Hall and McDermott (2007a).

3. Proietti (2006) has investigated the potential use of state space methods for temporal disaggregation purposes. He also refers to, but did not evaluate, the multivariate time series approaches of Harvey and Chung (2000) and Moauro and Savio (2005). These methods do not seem to have been widely used to date.

4. See http://www.stats.govt.nz/tables/ltds/default.htm.

5. The cointegration condition required for the Chow-Lin regression method is violated for the weighted amplitude adjusted index, and so that series is rejected in favor of the series without adjustment.

6. For details, see Hall and McDermott (2007a, fn 6).

7. Visually, there is minimal difference in the series derived from use of the Chow-Lin, Fernández and Litterman methods (Hall and McDermott, 2007a, Figs. 4 and 5), and their estimated cointegrating vectors are $(1, -1)$. We prefer to use observations estimated from the Chow-Lin regression. This is because the cointegration test cannot be rejected for the Chow-Lin regression, implying there is minor specification error in the Fernández and Litterman regressions. For additional detail, see Hall and McDermott (2007a, ss. 3–5).

8. The hypothesis of a unit root in the level of real GDP cannot be rejected at the 5% level, and is rejected at that level for the series' first differences.

9. The statistical properties for this subperiod should be treated with some caution, given it is only 28 quarters long. Its standard deviation and integrated normalized spectrum, in the usual business cycle frequency of 6–32 quarters, are between two and three times greater than those for the other subperiods and the full sample.

10. This issue is potentially very important, given that a major use of our series will be for business cycle analysis. This is because Romer (1986) and Watson (1994) found that, for U.S. industrial production and real GDP, prewar data were much narrower in focus than postwar data, and that previous findings of greater business cycle volatility and larger contractions for the prewar period were misleading. The previous findings were therefore largely a reflection of measurement error rather than different economic behavior.

11. For examples, see Kim, Buckle, and Hall (1995), who use the method to establish turning points for both production- and expenditure-based GDP series; and Hall and McDermott (2007b) who utilize National Bank of New Zealand regional activity data from 1975q1 to 2002q1 to establish turning points for regional economic activity.

12. For example, Harding and Pagan (2003a, Table 1, p. 1684) have used their quarterly algorithm to match closely the quarters in which monthly NBER turning points occur. Only for the trough of 1970q4 is there a discrepancy of more than one quarter. We know of no suitable monthly New Zealand series for which to conduct a similar comparison.

13. See Harding and Pagan (2003a, 2003b) and Hamilton (2003).

14. Of course, revisions to the historical times series can and do alter previously dated turning points. See Hall and McDermott (2007b, fn. 16).

15. Two potentially important additional issues arise when the BBQ quarterly program is used instead of its monthly equivalent (Harding and Pagan, 2002, pp. 368, 371). A 15-month minimum phase length could have either a four-quarter or five-quarter equivalent, and a smoothing step has much reduced benefit when quarterly data are used. BBQ omits the smoothing step, and Harding and Pagan's U.S. and Australian turning points were invariant to using four or five quarters as the restriction.

16. The data periods were 1947q1 to 1997q1 for the U.S. 1955q1 to 1997q1 for the U.K. and 1959q1 to 1997q1 for Australia.

17. See Pagan (2005, p. 12) for the CV figures for the U.S. covering the extended period 1947q1 to 2002q2.

18. For details, see Pagan (2005, pp. 8–12). Pagan cautions that the excess area measure may not be very reliable for contractions where these are very short, and that as a measure of "shape" of the cycle, it is not completely satisfactory where the phase line moves above and below the hypotenuse of the triangle.

19. Further attractions of the OTP-SB test (OTP, 2004, p. 533) are that it can be used to assess how duration dependence might have changed over time, and to investigate prediction issues.

20. These findings are consistent with the results reported in Hall and McDermott (2007b, Table 5) for turning points in National Bank of New Zealand (NBNZ) aggregate economic activity between 1975q1 and 2002q1.

21. Unfortunately, we cannot analyze contractions. Most contractions last a year or less, so an estimate of the durations of contractions cannot be obtained from annual data.

22. This research establishes net tax and government spending as having distinctively different effects.

23. A referee has suggested that our finding in Section 4 on lack of duration dependence provides an additional reason for exploring Markov-switching models, as these models do not have duration dependence.

24. Their 3-2 model has four states (classified, with three growth rates and two volatilities, as high growth–low volatility, low growth–high volatility, (unusually) high growth–low volatility, and (unusually) high growth–high volatility). BHT prefer this model to a variety of other Markov-switching models, including their 2-2 (high growth–low volatility, low growth–high volatility) model. They estimate their models by the method of maximum likelihood, following exploration of the likelihood surface using the EM algorithm.

25. Bayesian Gibbs-sampling has been used, instead of maximum likelihood, for practical rather than theoretical reasons. Recent advances in econometrics make Bayesian estimation of the regime switching model considerably easier to implement for this particular data series.

26. These results are available on request from the authors. The 3-3 model has three growth rates and three volatilities, with regimes of medium growth–very high volatility, low growth–high/medium volatility, and high growth–low volatility. The 3-2 model allows for only two volatilities, with medium growth–very high volatility, low growth–low/medium volatility, and high growth–low/medium volatility regimes. These more complex models seem over-parameterized for the available data. For example, in both cases, the estimates of very high volatility, covering primarily the relatively short 28-quarter first subperiod, are not statistically significant. Other estimates seem commensurately adversely affected.

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