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Key Features of Australian Business Cycles

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Key Features of Australian Business Cycles

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Abstract

This paper identifies and describes the key features of Australian business cycles during 1959-2000. In particular, we identify the chronologies in Australia's classical cycle (expansions and contractions in the level of output) and growth cycle (periods of above-trend and below-trend rates of economic growth). We find that while there are large asymmetries in the duration and amplitude of phases in Australia's classical cycle, on both measures the Australian growth cycle is much more symmetric. Further, our results indicate that over the sample period Australian (filtered) output and prices have moved in a counter-cyclical fashion, suggesting a dominance of shocks to aggregate supply affecting the Australian economy.

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I. Introduction

The study of business cycles, that is of the irregular pattern of fluctuations in economic activity, has a long history in economics. Since the seminal work of Burns and Mitchell (1946) and their colleagues at the National Bureau of Economic Research (NBER), work on cyclical instability has traditionally been concerned with analyzing the attributes of expansions and contractions in the level of economic activity or output (the classical cycle). In more recent decades, spurred by the contribution of Lucas (1977), business cycle fluctuations have become commonly viewed as deviations of real aggregate output from trend, and any associated stylized facts as the statistical properties of the comovement of deviations from trend of certain macroeconomic series with those of real aggregate output deviations. As such, modern business cycle analysis tends to view cyclical instability as concerned with analyzing the attributes of above-trend and below-trend rates of economic growth (the growth cycle).

This paper attempts to identify and describe some of the key features of Australian business cycles during the period 1959-2000, and will focus on several questions. What are the key stylized facts of Australian business cycles? Do expansions and contractions in the level of real output have similar features, and how do they compare with the business cycle defined as alternating periods of above- and below-average rates of economic growth? Is there any relationship between the duration and amplitude of output, or between the duration and amplitude of trend-adjusted output? Is there any support for the notion that expansions and contractions in either output or trend-adjusted output have a fixed duration? Finally, is there a positive or negative relationship between Australian (trend-adjusted) output and prices?

In examining these questions, our analysis of the attributes of Australian business cycles will cover both 'classical' cycles and 'growth' cycles. The classical cycle describes movements in actual economic time series, in particular the identification of expansions and contractions in the absolute level of aggregate economic activity (see Burns and Mitchell (1946)). In contrast, the growth cycle focuses on deviations in economic activity from a long-term trend, so that growth expansions (growth contractions) are described as periods when the growth rate is above (below) the long-term trend rate of growth in aggregate economic activity (see Hodrick and Prescott (1980), Kydland and Prescott (1990)).

As the growth cycle is defined in terms of deviations from trend, it is important to be clear as to the nature of detrending which is carried out on the output and price series analyzed in this paper. Existing studies of the Australian growth cycle are predicated on the view that it is necessary to start from a stationary series.[2] Applied researchers consequently use stationary-inducing transformations, which are known to yield distorted estimates of the growth cycle (see Baxter and King (1999) and Canova (1998)). Specific examples of such growth-cycle distorting transformations include removal of polynomial functions of time, first differencing, and the Hodrick-Prescott filter, among many others.

[2] Earlier studies of the Australian growth cycle have included Boehm and Moore (1984), Backus and Kehoe (1992), Fisher, Otto and Voss (1996), and Bodman (1998), among others.

In a recent paper, Ouliaris and Corbae (2002) suggest a new approach to estimating the growth cycle starting from the level of a time series. Using frequency domain techniques and recent developments in spectral regression for nonstationary time series, they propose an approximate 'ideal' band pass filter for estimating deviations from trend of a given periodicity. Ouliaris and Corbae show, using Monte Carlo simulations, that the new filter has superior statistical properties to the popular Baxter and King (1999) and Hodrick-Prescott (1980) filters. They also show that their filter, in contrast to the Baxter-King and Hodrick-Prescott filters, is statistically consistent in the sense that the filter series asymptotically converges to the true growth cycle.

In this paper we follow Baxter and King (1999) and define the 'growth cycle' as movements in real GDP over the classic (Burns and Mitchell (1946)) business cycle frequencies, namely cycles in GDP between 6 and 32 quarters. In addition, as an alternative form of evaluation to the abovementioned Monte Carlo simulations, we use a variant of the Bry and Boschan (1971) cycle-dating algorithm to compare the peaks and troughs identified in the Australian growth cycle by the Ouliaris-Corbae (OC) filter with: turning points derived using alternative filters; turning points derived by earlier researchers; and with turning points of the Australian classical cycle.

Following the work of Burns and Mitchell (1946), monthly dating of turning points in a composite index of several coincident time series (the reference cycle) thought to contain information on the current state of economic activity (such as GDP, factory production, retail sales and unemployment) have traditionally been used in describing the business cycle (see, for example, Boehm and Moore (1984)). In this paper we deviate from this approach, and follow King and Plosser (1994) and Canova (1999) in seeking to date quarterly turning points in economic activity. Accordingly, we use quarterly data on real GDP, the most comprehensive (and readily available) single measure of aggregate economic activity, to represent Australian business cycles.[3] In examining cycles in Australian GDP, we also attempt to bridge the often wide gap between NBER-type analyses of cycles in a composite index of activity, and modern business cycle facts which analyze the comovement of trend-adjusted macroeconomic variables and GDP.

In defining turning points and periods between turning points in Australian classical and growth cycles, we follow the taxonomy of Mintz (1972). For the classical cycle, turning points in real GDP are described as peaks and troughs, with periods between peaks and troughs (troughs and peaks) denoted as contraction (expansion) phases. For the growth cycle,

[3] Harding and Pagan (2001a) point out that an important spur to Burns and Mitchell's development of economic indices was the lack, *at that time*, of reliable measures of GDP, available at least at a quarterly frequency. This is not the case now, as Australia has a long time series of quarterly measures of GDP. Canova (1999) argues that using real GDP to represent the business cycle has the advantage of being readily reproducible and of eliminating judgemental aspects of the selection of turning points in a reference cycle.

turning points in filtered real GDP are described as downturns and upturns, with periods between downturns and upturns (upturns and downturns) denoted as low-rate (high-rate) growth phases. In a growing economy high-rate phases must coincide with expansion phases in the classical cycle, yet low-rate phases may be associated with either phase of the classical cycle. However, classical contraction phases must be associated with low-rate phases in the growth cycle. While growth-cycle downturns tend to lead classical-cycle peaks, growth-cycle upturns tend to coincide with or lag classical-cycle troughs.[4] Accordingly, we should expect that high-rate phases will tend to be shorter-lived than expansion phases, and that low-rate phases will tend to be longer-lived than contraction phases. While periods of low growth are likely to be dissimilar from periods of absolute decline in output, it has been observed that periods of relative and absolute decline may bear some resemblance in their typical duration and in the 'shape' of their phase movements, and these features will be examined in this study (Mintz (1972)).

Although there is a long tradition of viewing classical cycles in terms of turning points, the recent literature on growth cycles has (apart from Canova (1999)) tended to neglect the issue of the timing of deviations from trend, preferring instead to concentrate on the analysis of the variances of filtered time series and on the covariances of movements in selected key series with filtered output. The aim of this paper is to provide classical and growth cycle chronologies for Australia from 1959, and to identify key features of Australian business cycles since that time. For both types of business cycle, we present statistics summarizing the key features, including: the duration and amplitude of phase movements in Australian GDP; whether cycles exhibit persistence (have similar 'shapes'), in that there is a relationship between the amplitude (severity) and duration of phase movements in GDP; and whether phase movements in GDP are more likely to terminate as their durations are extended, and thereby exhibit duration dependence.

The plan of this paper is as follows. In Section II, we outline the econometric theory behind the frequency domain filter. In Section III, we use this filter to identify the Australian growth cycle. Using two variants of the Bry and Boschan (1971) cycle-dating algorithm, we provide a chronology for each of the Australian classical and growth cycles in Section IV. We also compare and contrast key features of the resultant phases of the two business cycles, and investigate the relationship between Australian output and prices (both adjusted for their long-run trends) over the classic business cycle frequencies. Section V concludes.

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[4] For an excellent summary of the relationship between classical and growth cycles, see Boehm and Liew (1994). Mintz (1972, p.44) points out that while classical cycles are described by turning points in economic activity, growth cycles are described by turning points in economic activity *adjusted for their long-run trends.* As such, in the absence of trend factors, classical and growth cycles are identical.

II. Extracting Business Cycles from Nonstationary Data

If one accepts the Burns and Mitchell (1946) definition of the business cycle as fluctuations in the level of a series within a specified range of periodicities, then the ideal filter is simply a band-pass filter that extracts components of the time series with periodic fluctuations between 6 and 32 quarters (see Baxter and King (1999)).[5] It can be shown that the exact band-pass filter is a double-sided moving average of the original series of infinite order, and with known weights. It follows that if we want to estimate the filter starting from the time-domain, an approximation to the correct result is needed. In this section we outline a frequency domain procedure for approximating the ideal band-pass filter, originally suggested in Ouliaris and Corbae (2002), which overcomes some of the shortcomings of the Hodrick-Prescott (1980) and Baxter-King (1999) time-domain based filters.

Assume that x_t ($t = 1, \ldots, n$) is an observable time series (e.g., real GDP) generated by:

$$x_t = \Pi_2' z_t + \tilde{x}_t, \tag{1}$$

where z_t is a p+1-dimensional deterministic sequence and $\tilde{x}_t$ is a zero mean time series. The series x_t therefore has both a deterministic component involving the sequence x_t and a stochastic (latent) component $\tilde{x}_t$. In developing their approach to estimating ideal band pass filters, Ouliaris and Corbae (2002) make the following assumptions about z_t and $\tilde{x}_t$.

Assumption 1

$z_t = (1, t, \ldots, t^p)'$ *is a* p^{th} *order polynomial in time.*

Assumption 2

$\tilde{x}_t$ *is an integrated process of order one (I(1) process) satisfying* $\Delta\tilde{x}_t = v_t$, *initialized at* $t = 0$ *by any* $O_p(1)$ *random variable. We assume that* v_t *has a Wold representation* $v_t = \sum_{j=0}^{\infty} c_j \xi_{t-j}$ *where* $\xi_t = iid\,(0, \sigma^2)$ *with finite fourth moments and coefficients* c_j *satisfying* $\sum_{j=0}^{\infty} j^{1/2} |c_j| < \infty$. *The spectral density of* v_t *is* $f_{vv}(\lambda) > 0, \forall\lambda$.

[5] This definition of the growth cycle is not necessarily accepted by all researchers of the business cycle, including perhaps Burns and Mitchell themselves. For example, Harding and Pagan (2001a) would include movements in trend (or zero frequency elements) as a fundamental part of cyclical movements.

Assumption 2 suffices for partial sums of v_t to satisfy the functional law $n^{-1/2}\sum_{t=1}^{[nr]} v_t \xrightarrow{d} B(r) = BM(\Omega)$, a univariate Brownian motion with variance $\Omega = 2\pi f_{vv}(0)$ (e.g., Phillips and Solo (1992), theorem 3.4), and where $\xrightarrow{d}$ is used to denote weak convergence of the associated probability measures as the sample size $n \to \infty$. We now state the result that motivates the new filtering procedure.

Lemma B (Corbae, Ouliaris, and Phillips (2002)) *Let $\tilde{x}_t$ be an* I(1) *process satisfying Assumption 2. Then, the discrete Fourier transform of $\tilde{x}_t$ for $\lambda_s \neq 0$ is given by:*

$$w_{\tilde{x}}(\lambda_s) = \frac{1}{1-e^{i\lambda_s}} w_v(\lambda_s) - \frac{e^{i\lambda_s}}{1-e^{i\lambda_s}} \frac{[\tilde{x}_n - \tilde{x}_0]}{n^{1/2}} \tag{2}$$

where the discrete Fourier transform (dft) of $\{a_t\, ; t = 1, \ldots, n\}$ is written $w_a(\lambda) = \frac{1}{\sqrt{n}}\sum_{t=1}^{n} a_t e^{i\lambda_t}$, *and* $\{\lambda_s = \frac{2\pi s}{n}, s = 0,1,\ldots,n-1\}$ *are the fundamental frequencies.*

Equation (2) shows that the discrete Fourier transforms of an I(1) process are not asymptotically independent across fundamental frequencies. They are actually frequency-wise dependent by virtue of the component $n^{-1/2}\,\tilde{x}_n$, which produces a common leakage into all frequencies $\lambda_s \neq 0$, even in the limit as $n \to \infty$. Corbae, Ouliaris, and Phillips (2002) also show that the leakage is still manifest when the data are first detrended in the time domain. These results on leakage show that in the presence of I(1) variables, any frequency domain estimate of the "cyclical" component of a time series (e.g., real GDP) will be badly distorted.

Ouliaris and Corbae (2002) suggest a simple "frequency domain fix" to this problem, which is derived from equation (2). Note that the second expression in equation (2) can be rewritten using

$$w_{t/n}(\lambda_s) = \frac{-1}{\sqrt{n}}\left(\frac{e^{i\lambda_s}}{1-e^{i\lambda_s}}\right)$$

by Lemma B of Corbae, Ouliaris, and Phillips (2002). Thus, even for the case where there is no deterministic trend in equation (1), it is clear from the second term in equation (2), which is a deterministic trend in the frequency domain with a random coefficient $[\tilde{x}_n - \tilde{x}_0]$, that all we need to do is detrend in the frequency domain to remove the leakage from the low frequency, leaving an asymptotically unbiased estimate of the first term $\frac{1}{1-e^{i\lambda_s}} w_v(\lambda_s)$. It follows that applying the indicator function $\beta(\lambda_s)$ for λ_s in a given frequency band to $w_{\tilde{x}}$ yields an unbiased estimate of the Fourier transform of the filtered data, whose inverse can be shown to be a $\sqrt{n}$ consistent estimate of the ideal band pass filter over the relevant frequencies. Provided this indicator function eliminates all frequencies outside the [6, 32] quarter range, the filter will provide an estimate of the growth cycle over the classic business cycle frequencies.

III. Estimating the Australian Growth Cycle

We now use the OC filter to investigate the behavior of Australia's real GDP and prices relative to trend over the classic business cycle frequencies. To measure real output we use the logarithm of seasonally adjusted, quarterly real GDP (in millions of Australian dollars, chain volume measures, reference year 1998-99), and as the measure of the aggregate price level we use the logarithm of the (quarterly) GDP deflator, both for the period 1959:3-2000:4.[6] Australia's real GDP and price level during this period are shown in Figure 1.

As stated above, following Baxter and King (1999), our definition of the growth cycle is all variations in the level of real GDP between 6 and 32 quarters. As this formulation excludes the long run or zero frequency component of the data, this definition of the growth cycle measures movements in real GDP relative to an unspecified (possibly nonlinear) trend. We also compare the new filter with the Hodrick-Prescott (HP) and Baxter-King (BK) filters to provide a comparison with existing approaches in the literature.

The standard deviation, skewness, and kurtosis of the growth cycle (filtered Australian GDP) extracted by each filter are given in Table 1.[7] Irrespective of the filtering method used, there is negative skewness in real GDP, indicating that there appear to be slightly larger downward spikes in real GDP than upward spikes (see Figure 2). Similarly, real GDP displays kurtosis, with tails thicker than the normal distribution (platykurtic), indicating that large real GDP movements are relatively common. Using skewness as our summary measure of the severity of recessions, the OC filter suggests milder recessions than the HP and BK filters, and is prima facie evidence that the choice of a particular filter can generate substantially different estimates of the probability distribution of cyclical movements.

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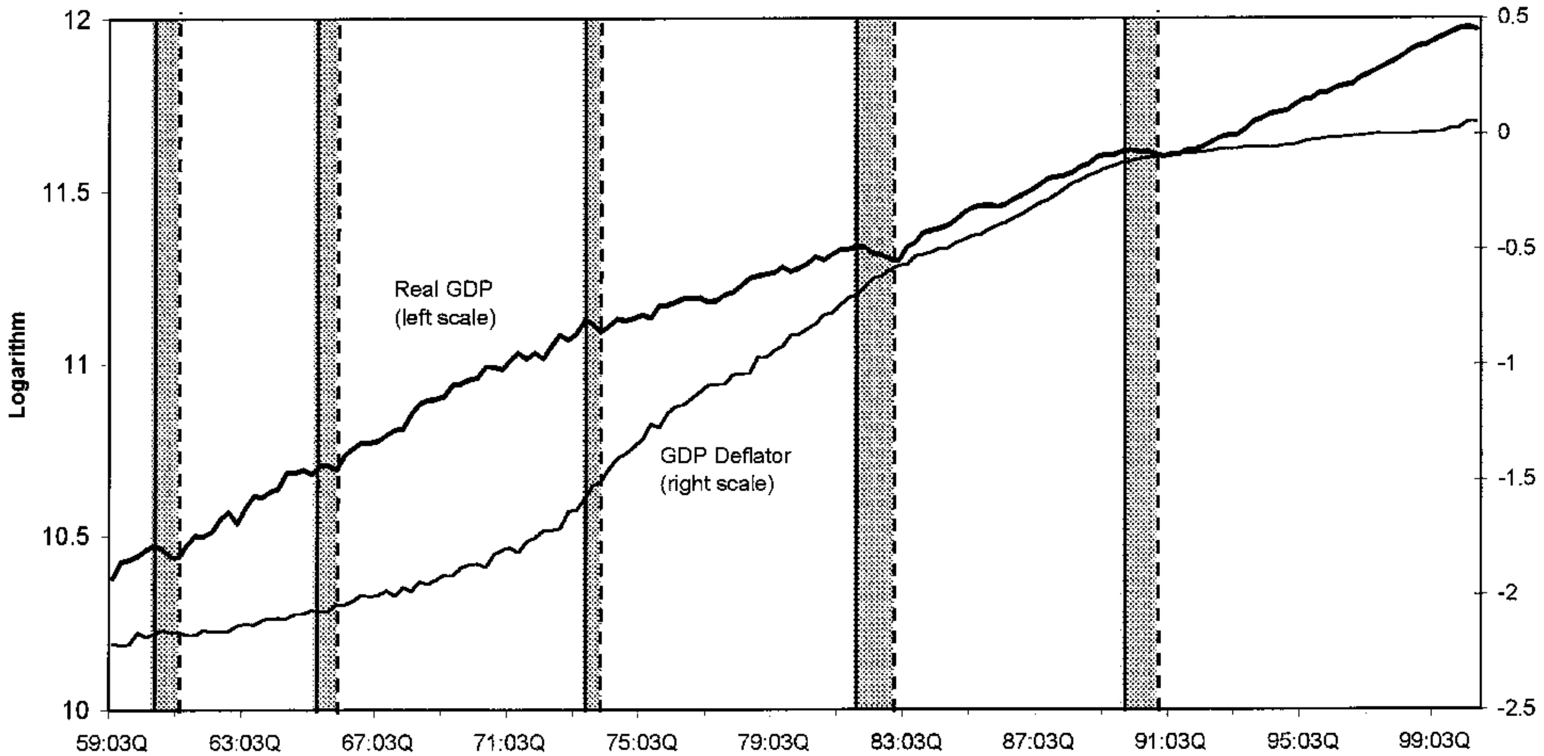
[6] The official data used in this paper are from the Reserve Bank of Australia's website, in particular its Tables G.9 (Gross Domestic Product) and G.10 (Gross Domestic Product—Expenditure Components). The GDP deflator series (base 1998-99) is the ratio of seasonally adjusted current-price GDP to constant-price (chain-volume measure) GDP.

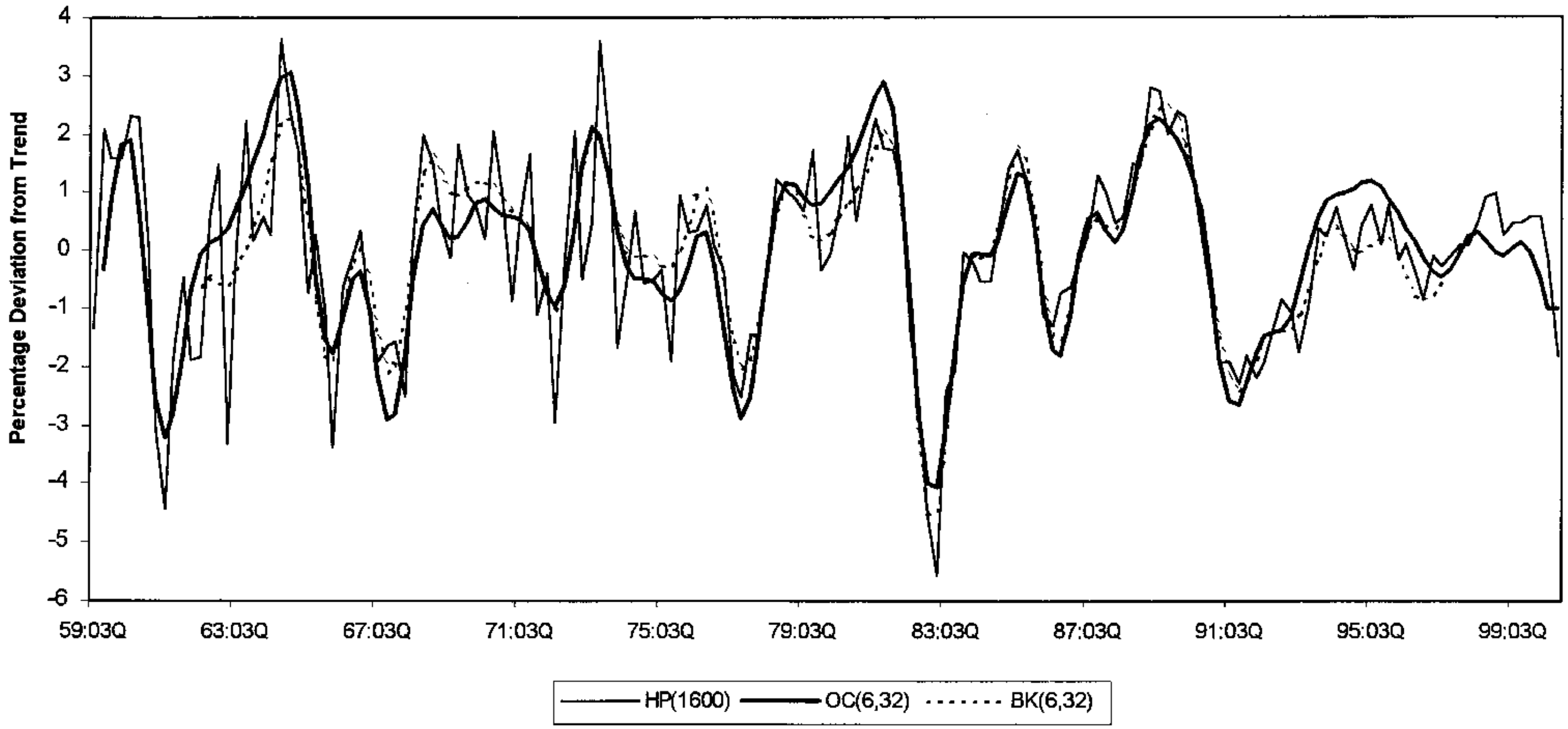
[7] These are the same moments considered by Canova (1998).

Figure 1. Australia: Real GDP and the Price Level, 1959:3-2000:4



Notes: Peaks in Australian real GDP are denoted by solid lines; troughs in Australian real GDP are denoted by dashed lines. Contractions (periods of peak to trough movement) are denoted by shading, while expansions (periods of trough to peak movement) are denoted by no shading.

Figure 2. Australia: HP(1600), BK (6,32), and OC(6,32) Estimates of Real GDP Growth Cycle, 1959:3-2000:4



Notes: HP denotes the Hodrick-Prescott (1980) filtered real GDP; BK denotes the Baxter-King (1999) filtered real GDP; and OC denotes the Ouliaris-Corbae (2002) filtered real GDP.

Table 1: Summary Statistics for the Australian Growth Cycle, 1959:3-2000:4

	HP	**BK**	**OC**
Standard Deviation	1.547	1.312	1.436
Skewness	-0.548	-0.635	-0.393
Kurtosis	0.680	0.805	-0.047

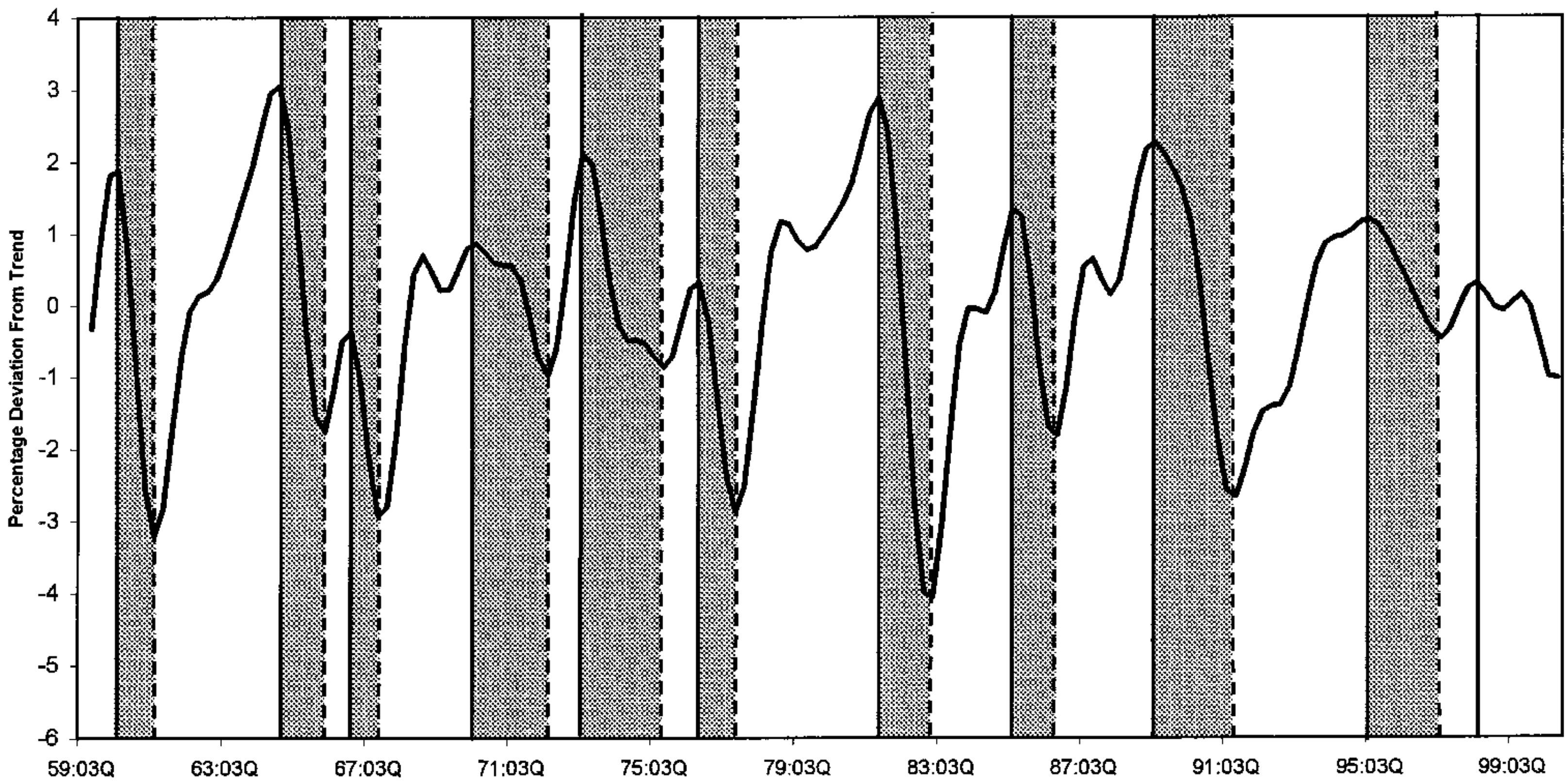
Notes: HP denotes the Hodrick-Prescott (1980) filtered GDP; BK denotes the Baxter-King (1999) filtered GDP; OC denotes the Ouliaris-Corbae (2002) filtered GDP. The skewness measure is $\mu_3/(\mu_2)^{1.5}$ and the kurtosis measure is $\mu_4/(\mu_2)^2$, where μ_r is the r^{th} (central) moment. The skewness of a symmetrical distribution, such as the normal, is zero; similarly, the kurtosis of the normal distribution is 3.

We plot the filtered data employing the three different filtering methods in Figure 2. Given that we are measuring the series in logs, the figure reflects smoothed deviations from potential output or trend in percentage terms. It is clear from the figure that the HP filter has too much of the irregular or "high-frequency" component of the original series to be a plausible estimate of the growth cycle over the classic business cycle frequencies.

The OC filter produces a smoother estimate of the growth cycle over the classic business cycle frequencies, and yields an estimate of the growth cycle which is very similar to that produced by the BK filter. However, unlike the BK filter, the OC filter can generate estimates of the cycle at the end points of a series, a feature that is likely to be particularly useful in forecasting exercises. Lastly, we remark that all three filters yield similar estimates of the location of downswings and upswings in the Australian growth cycle (that is, peaks and troughs relative to trend), particularly if we take the additional step of smoothing the HP filter to remove excessive irregular movements.

Figure 3 displays Australia's filtered (or detrended) GDP, derived using the OC filter. There are several downswings and upswings in this series, with the period between these turning points being described as the low-rate and high-rate phases of the Australian growth cycle. Clearly, there are several phases which are rather short-lived, and it is unlikely that an upturn (downturn) in economic growth would be called on the basis of only one or two quarters of above-trend (below-trend) growth. In order to discern the duration of low-rate and high-rate phases of the Australian growth cycle, we implement a version of the Bry-Boschan (1971) algorithm to isolate patterns in the growth cycle data by following a sequence of rules. We also use another variant of the Bry-Boschan algorithm to isolate patterns in the movement of real GDP, in order to discern turning points in the Australian classical cycle (see Figure 1).

Figure 3. Australia: OC(6,32) Estimate of Real GDP Growth Cycle, 1959:3-2000:4



Notes: OC denotes Ouliaris-Corbae (2002) filtered real GDP. Turning points in filtered Australian real GDP are described as downturns (denoted by solid lines) and upturns (denoted by dashed lines). Low-rate growth phases (periods of downturn to upturn movement) are denoted by shading; high-rate growth phases (periods of upturn to downturn movement) are denoted by no shading.

IV. DATING AUSTRALIAN BUSINESS CYCLES USING BRY-BOSCHAN METHODS

The duration of phases of the Australian growth cycle can be determined with the assistance of an algorithm traditionally used to date turning points in classical cycles—that of Bry and Boschan (1971). The rules embodied in the Bry-Boschan algorithm have evolved from the NBER's dating of cycles in U.S. economic activity. The algorithm has been used previously to automate the dating of cycles in the level of various time series (see King and Plosser (1994), Watson (1994), and Harding and Pagan (2001a)). Pagan (1999) has also applied the algorithm to date bull and bear markets in equity prices, as have Cashin, McDermott and Scott (2002) in dating commodity-price cycles.[8]

Accordingly, here we use the standard rules embodied in the Bry-Boschan algorithm (which automates NBER approaches to the dating of turning points in classical cycles) to determine when Australia's real GDP is in an expansionary or a contractionary phase. We also adapt the algorithm to determine when Australia's real GDP is in a relatively high or relatively low phase of economic growth (in order to date turning points in growth cycles).

The Bry and Boschan algorithm attempts to filter out false turning points from noisy data, and as the algorithm is basically a pattern-recognition procedure, the philosophy underlying it is relevant to any time series. The first step in the algorithm determines the location of potential peaks and troughs. This is done by the application of a turning point rule, which finds points that are higher or lower than an arbitrary window of surrounding points. The rule defines a local peak in series y_t as occurring at time t whenever $\{ y_t > y_{t\pm k} \}$, $k = 1, ..., K$, while a local trough occurs at time t whenever $\{ y_t < y_{t\pm k} \}$, $k = 1, ..., K$. The second step enforces the condition that peaks and troughs must alternate. The third step measures the duration between these points, and a set of censoring rules is then adopted which restrict the minimum length of any phase as well as those of complete cycles. There are further rules designed to avoid spurious cycle dating at the ends of series (for details see Appendix I). When the peaks and troughs in each of the time series have been dated, key features of these cycles can be measured.

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[8] Harding and Pagan (2001b) argue that nonparametric approaches to ascertaining turning points in the business cycle (such as the Bry-Boschan algorithm) compare favorably with that of parametric approaches (such as the Markov switching model), due to the former's greater transparency, simplicity and robustness to variations in the sample selected. For an application of the Markov switching model to the dating of turning points in the Australian growth cycle, see Bodman and Crosby (2001).

A. Chronology of the Australian Classical Cycle

As used by the NBER, the Bry-Boschan algorithm was originally applied to monthly data in the levels of each measure of economic activity, to derive turning points in the classical reference cycle. The NBER rules for data at monthly frequency generally set K=5, with complete cycles at least 15 months long and all phases at least 6 months long. In applying these rules to quarterly GDP data, we follow Harding and Pagan (2001a) and set K=2. This ensures that y_t is a local maximum relative to the two quarters on either side of y_t. In determining the minimum time the Australian GDP series can spend in any phase (expansion or contraction) or cycle, we follow the rule used by Burns and Mitchell (1946) and Harding and Pagan (2001a) in business-cycle dating, which requires cycles to be at least five quarters in duration, and phases (GDP expansions and contractions) must last at least two quarters.[9] Contractions are then described as periods of absolute decline in the Australian GDP series, not as a period of below-trend growth in the series (see Watson (1994)). Figure 1 presents the Bry-Boschan peak and trough dates for Australian real GDP. The dashed lines represent the trough dates and the solid lines the peaks, with contractions (peak to trough movements) denoted by shading and expansions (trough to peak movements) denoted by no shading.[10] Compared with expansions, it is clear that contractions (absolute declines) in Australian real GDP are relatively rare, and short-lived, events.

B. Chronology of the Australian Growth Cycle

The variant of the Bry and Boschan-type algorithm used here to date the Australian growth cycle involves several modifications to the Bry-Boschan classical cycle-dating algorithm outlined above. In dating the growth cycle a simple application of the abovementioned business cycle-dating rules would be inappropriate, as the likelihood of two quarters of below-trend growth in a low-rate phase of the growth cycle is much greater than the likelihood of two quarters of declining output in a contractionary phase of the classical cycle. Accordingly, we follow Dungey and Pagan (2000) in adapting the Bry and Boschan algorithm to date growth cycles, by requiring that completed growth cycles be at least six quarters in duration, and growth-cycle phases (high-rate and low-rate phases) must last at least three quarters. In addition, to avoid spurious turning points we want to rule out mild interruptions in growth-cycle phases. Accordingly, any potential change of phase that moves the growth cycle by less than one-half of one percent is ruled out as being a turning point.[11]

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[9] Appendix I sets out the algorithm used to date turning points in the classical cycle.

[10] Previous uses of the Bry-Boschan turning point algorithm to provide a chronology for Australian business cycles have been provided by, among others, Boehm and Moore (1984), Layton (1997), Pagan (1997) and Harding and Pagan (2001a).

[11] This additional censoring rule affects the determination of one turning point. A short-lived (three quarters) low-rate phase of 0.4 percent in 1979, which occurred in the middle of a period of above-trend growth, is not considered a true turning point.

Low-rate (high-rate) phases are then described as periods of below-trend (above-trend) growth in Australian real GDP, and so this variant of the Bry and Boschan algorithm dates "growth cycles", as described by Mintz (1972). Figure 3 presents the Bry-Boschan downturn and upturn dates for Australian real GDP growth. The dashed lines represent the upturn dates and the solid lines the downturns, with low-rate phases (periods of downturn to upturn movement) denoted by shading and high-rate phases (periods of upturn to downturn movement) denoted by no shading. In contrast to the classical cycle, low-rate phases are relatively frequent, and often long-lived, events.[12]

C. Comparison of Classical and Growth Cycles

Tables 2 and 3 set out the results of applying these variants of the Bry-Boschan algorithm to provide a chronology for cycles in Australian real GDP and real GDP growth. They also present the statistical properties of the classical and growth cycles, in particular the duration and amplitude characteristics of their phase movements.

There are clearly more turning points in the Australian growth cycle than in the Australian classical cycle, with 4 completed (peak-to-peak) classical cycles and 10 completed (downturn-to-downturn) growth cycles over the sample period. Since 1959 there have been five contractionary phases of the classical cycle, with many more (ten) periods of low-rate (below-trend) phases of the growth cycle. On five occasions, low-rate phases of the growth cycle interrupted classical expansions, but did not terminate them. As shown in Table 2, downturns in the Australian growth cycle tend to lead peaks in the Australian classical cycle, while upturns in the Australian growth cycle tend to be coincident with (or slightly lag) troughs in the Australian classical cycle.[13] Interestingly, while real GDP was in a contractionary phase only about 10 percent of the time between 1959-2000, real GDP growth was below trend about 42 percent of the time during the same period.

[12] It should be noted that the final low-rate phase of the Australian growth cycle has not been completed, and so the unshaded portion of Figure 3 following 1998:3 (the latest downturn in the growth cycle) is indeterminate, and is not a high-rate phase of the growth cycle (as are all preceding unshaded regions).

[13] In contrast to downturns in growth cycles being predictors of classical peaks, upturns in growth cycles coincide with classical troughs in three of the five cases, and lag troughs in the remaining cases.

Table 2. Australia: Phases of Business Cycles, 1959:3-2000:4

Turning Point Date (quarter and year) -		Australian Classical Cycles				Turning Point Date (quarter and year)		Australian Growth Cycles			
Peak (P)	Trough (T)	Contraction Duration (P to T)	Expansion Duration (T to P)	Cycle Duration (P to P)	Cycle Duration (T to T)	Down-turn (D)	Up-turn (U)	Low-rate Duration (D to U)	High-rate Duration (U to D)	Cycle Duration (D to D)	Cycle Duration (U to U)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1960:4	1961:3	3									
1965:4	1966:2	2	17	20	19	1960:3	1961:3	4			
1973:4	1974:2	2	30	32	32	1965:1	1966:2	5	14	18	19
1982:1	1983:2	5	31	33	36	1967:1	1967:4	3	3	8	6
1990:2	1991:2	4	28	33	32	1970:3	1972:3	8	11	14	19
						1973:3	1975:4	9	4	12	13
						1976:4	1977:4	4	4	13	8
						1981:4	1983:2	6	16	20	22
						1985:3	1986:4	5	9	15	14
						1989:3	1991:4	9	11	16	20
						1995:3	1997:3	8	15	24	23
						1998:3			4	12	
Average		3.20	26.50	29.50	29.75			6.10	9.10	15.20	16.00
Median		3.00	29.00	32.50	32.00			5.50	10.00	14.50	19.00
Std. Deviation		1.30	6.45	6.35	7.41			2.23	5.04	4.57	6.08

Notes: For each of the two cycles (classical and growth), and for each of two phases (expansion and contraction for the classical cycle; high-rate and low-rate for the growth cycle), three sets of results are presented. These are: the turning points of each phase; the average duration (in quarters) of each phase; and the average duration (in quarters) of each cycle.

Table 3. Duration and Amplitude of Phases, Australian Business Cycles, 1959:3-2000:4

Period (1)	Duration (2)	Amplitude (3)	Quarterly Amplitude (4)	Period (5)	Duration (6)	Amplitude (7)	Quarterly Amplitude (8)
			Australian Classical Cycles				
		Contraction Phase				Expansion Phase	
1960:4-61:3	3	-3.3	-1.1	1961:3-65:4	17	23.4	1.4
1965:4-66:2	2	-1.0	-0.5	1966:2-73:4	30	35.2	1.2
1973:4-74:2	2	-3.6	-1.8	1974:2-82:1	31	21.9	0.7
1982:1-83:2	5	-3.8	-0.8	1983:2-90:2	28	27.3	1.0
1990:2-91:2	4	-1.9	-0.5	1991:2-			
Average	3.20	-2.69	-0.92		26.50	26.92	1.06
Std. Deviation	1.30	1.21	0.54		6.45	5.96	0.29
Coeff. Of Variation	0.41	0.45	0.59		0.24	0.22	0.27
			Australian Growth Cycles				
		Low-rate Phase				High-rate Phase	
1960:3-61:3	4	-5.1	-1.3	1961:3-65:1	14	6.0	0.4
1965:1-66:2	5	-4.7	-0.9	1966:2-67:1	3	1.4	0.5
1967:1-67:4	3	-2.5	-0.8	1967:4-70:3	11	3.8	0.3
1970:3-72:3	8	-1.8	-0.2	1972:3-73:3	4	3.0	0.7
1973:3-75:4	9	-2.9	-0.3	1975:4-76:4	4	1.2	0.3
1976:4-77:4	4	-3.1	-0.8	1977:4-81:4	16	5.7	0.4
1981:4-83:2	6	-6.7	-1.1	1983:2-85:3	9	5.2	0.6
1985:3-86:4	5	-3.0	-0.6	1986:4-89:3	11	4.1	0.4
1989:3-91:4	9	-4.9	-0.6	1991:4-95:3	15	3.8	0.3
1995:3-97:3	8	-1.5	-0.2	1997:3-98:3	4	0.8	0.2
1998:3-							
Average	6.10	-3.63	-0.68		9.10	3.47	0.40
Std. Deviation	2.23	1.66	0.37		5.04	1.88	0.16
Coeff. Of Variation	0.37	0.46	0.54		0.55	0.54	0.40

Notes: For each of the two cycles (classical and growth), and for each of two phases (expansion and contraction for the classical cycle; high-rate and low-rate for the growth cycle), four results are presented. First, the dates of each peak-to-trough (downturn-to-upturn) movement and trough-to-peak (upturn-to-downturn) movement. Second, the duration (in quarters) of each phase. Third, the amplitude of the aggregate phase movement in output (in percent change) for each phase. Fourth, the quarterly amplitude (amplitude divided by the duration) for each phase.

In addition to information on the attributes of real GDP and GDP growth cycles, we also report on the salient features of movements in real GDP and real GDP growth between these turning points (Table 3). For each of the two series, the table splits the data into two phases—expansion and contraction phases (for the classical cycle) and high-rate and low-rate phases (for the growth cycle). For each phase, we present results for: the average duration (in quarters) of the phase; the average amplitude of the aggregate phase movement in output (in percent change); and the average quarterly amplitude (amplitude divided by the duration).

The results in Table 3 imply that an important stylized fact of classical cycles is that they are asymmetric—contractions in real GDP are considerably shorter in duration than real GDP expansions. The typical length of contractions (about 3 quarters) is about one-ninth as long as the typical length of expansions, giving an average cycle (peak-trough-peak movement) of about 29 quarters. The amplitude (percent change) measure shows that the average decline in real GDP during contractions (about 2.7 percent) is considerably smaller than the average rise during expansions (about 27 percent). This differing relative amplitude results in an overall upward trend in real GDP. The speed with which real GDP changes in contractions in comparison with expansions can be determined by examining the relative quarterly amplitude. The average quarterly amplitude of real GDP rises in expansions (1.1 percent a quarter) is slightly faster than the quarterly amplitude of real GDP declines in contractions (0.9 percent a quarter).

In contrast to the classical cycle, the Australian growth cycle is much more symmetric. Typical low-rate phases last about 6 quarters, while typical high-rate phases are slightly longer at about 9 quarters, with the average amplitude of high-rate phases slightly smaller than the amplitude of low-rate phases. The speed of change of Australian growth-cycle phases is slightly faster for low-rate phases than for high-rate phases (Table 3).[14]

In comparing phases of classical and growth cycles, the average classical cycle is almost twice as long as the average growth cycle. We also find that high-rate phases (of the Australian growth cycle) tend to be shorter-lived than classical expansion phases, and low-rate phases tend to be longer-lived than contraction phases. The duration of classical expansion phases has also varied much less about its mean than has the duration of high-rate phases of the growth cycle (the coefficient of variation in the latter is more than double that of the former).

Our results for classical and growth cycles in Australian output can be compared with those in the existing literature on Australian business cycles. The mean duration and amplitude of expansions and contractions found here for the classical cycle are close to those derived by Harding and Pagan (2001a) using a Bry and Boschan (1971)-type algorithm. The turning

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[14] This finding is consistent with Pagan's (1997) analysis of growth cycles in the Australian composite coincident index, where it was found that high-rate phases typically last about 50 percent longer than low-rate phases.

points in the classical cycle are close to those obtained by Boehm and Summers (1999) for real GDP, after allowing that we have used quarterly data (as opposed to their use of monthly data). However, we locate two classical cycles (in the mid-1960s and mid-1970s) not found by Boehm and Summers. As to the growth cycle, our use of the OC filter has generated the same number of growth cycles as found by Boehm and Summers, with broadly similar turning points (an exception being the high-rate period of the late 1980s). Our results are also broadly similar to the measures of the duration of classical and growth cycles in the Australian composite coincident index obtained by Boehm and Liew (1994) and Pagan (1997).[15]

D. Nonparametric Tests of Features of Australian Business Cycles

We also use some formal nonparametric tests to provide additional information on the nature of both the expansionary and contractionary phases in real GDP, and the high-rate and low-rate phases in real GDP growth. In particular, we use the Spearman rank correlation test and the Brain-Shapiro (1983) test of duration dependence, in order to examine whether there are similarities in the phases of Australian business cycles.

The Spearman rank correlation statistic provides a measure of whether there is a significant relationship between the severity (absolute amplitude) of expansions and their duration, and the severity of contractions and their duration. The null hypothesis of the Spearman rank correlation test is that there is no rank correlation between the amplitude of an expansion (contraction) and the duration of that expansion (contraction). Following Harding and Pagan (2001a), if we consider the duration and amplitude of a phase as two sides of a right-angled triangle, where the height of the triangle is the amplitude and the base of the triangle is the duration, then we can view this as a test of whether the phases of the classical cycle consistently have the same 'shape' (that is, the same angle of the hypotenuse).

We also examine whether there is any tendency for expansions and contractions in real GDP to maintain a fixed duration. If true, this would imply duration dependence—the longer any expansion or contraction phase continues, the more likely it is to switch to the other phase. Accordingly, we follow Diebold and Rudebusch (1992) and calculate the Brain-Shapiro statistic for duration dependence, which tests whether the probability of ending an expansion or contraction in a series is dependent on how long the series has been in that expansion or contraction. The null hypothesis of the Brain-Shapiro statistic is that the probability of exiting a phase is independent of the length of time a series has been in that phase. The two possible

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[15] Canova (1999) finds that among many commonly-used filters, frequency domain filters of the type used in this paper, applied to U.S. real GDP, are best able to replicate the properties of NBER growth cycles. He argues that such filters, due to their ability to extract both deterministic and stochastic trends from the data, are consistent with Pagan's (1997) finding that a random walk with drift (without drift) is the best representation of the data-generating process that yields the typical duration and symmetry properties of the phases of classical (growth) cycles.

alternatives are that either: (i) the longer an expansion or contraction persists, the greater the likelihood that the expansion or contraction will terminate (positive duration dependence); or (ii) the longer an expansion or contraction persists, the greater the likelihood that the expansion or contraction will be self-perpetuating, and hence the lower the likelihood that the expansion or contraction will terminate (negative duration dependence). The distribution of the Brain-Shapiro statistic is asymptotically $N(0,1)$, which it quickly approaches even in small samples.[16]

Similarly, for the Australian growth cycle we examine whether there is a significant relationship between the severity (absolute amplitude) of high-rate phases and their duration, and the severity of low-rate phases and their duration. We can also examine whether there is any tendency for high-rate and low-rate phases of the Australian growth cycle to maintain a fixed duration. The results of both the rank correlation and duration dependence tests are reported in Table 4.

Table 4. Australia: Nonparametric Tests on the Nature of Contractions and Expansions in Real GDP and Real GDP Growth, 1959:3-2000:4

	Contraction Phase		Expansion Phase	
	Brain-Shapiro	Spearman	Brain-Shapiro	Spearman
Real GDP	0.50	0.60	-1.22	-0.20
	Low-rate Phase		High-rate Phase	
	Brain-Shapiro	Spearman	Brain-Shapiro	Spearman
Real GDP Growth	-1.01	-0.13	-0.39	0.75*

Notes: There are two types of phases for Australian business cycles: the classical cycle is categorized into periods of expansionary or contractionary phases in real GDP; the growth cycle is categorized into periods of low-rate (that is, below trend) and high-rate (above trend) phases in the growth of real GDP. The Brain-Shapiro statistic is an examination of duration dependence in the phases of real GDP and real GDP growth. The null hypothesis of the Brain-Shapiro statistic is that the probability of terminating a phase is independent of the length of time a series has been in that phase. An asterisk denotes that the null hypothesis is rejected (using a 5 percent critical value for a two-tailed test)—any result greater than the critical value of 1.96 (in absolute value) indicates duration dependence in the series. The Spearman rank correlation coefficient examines whether there is any relationship between the duration and amplitude of a phase. The null hypothesis is no rank correlation between the amplitude of a phase and its duration. An asterisk denotes that the null hypothesis is rejected (using a one-tailed test) at the 5 percent level of significance, where $1.65/N^{1/2}$ gives the five percent critical value for significant correlations, where N is the number of expansions or contractions in the sample period. For the period 1959:3-2000:4, the number of expansion (E) and contraction (C) phases in GDP, and high-rate (H) and low-rate (L) phases in GDP growth are: (E=4, C=5 (GDP), H=10, L=10 (GDP growth)).

[16] A negative (positive) Brain-Shapiro statistic is associated with positive (negative) duration dependence (see Diebold and Rudebusch (1992)).

For the growth cycle, the Spearman rank correlation statistic indicates that there is a relationship between the severity (absolute amplitude) of high-rate phases and their duration, and so there is some evidence of a consistent shape to high-rate phases. This feature is not found for low-rate phases of the growth cycle. For expansions and contractions in real GDP (the classical cycle), the null hypothesis of no rank correlation between the amplitude of an expansion in real GDP (contraction in real GDP) and the duration of the expansion (contraction) could not be rejected for either phase.

For the growth cycle, the Brain-Shapiro statistic indicates that the termination probability of both low-rate and high-rate phases did not change the longer the phase lasted. Similarly, the probability of a contraction or expansion in real GDP ending was independent of its duration. While not significant, the positive duration dependence in high-rate and low-rate phases (given the negative Brain-Shapiro statistic) indicates that the longer high-rate or low-rate phases continued, the greater was the probability of switching to the other phase.[17]

To compare the implications for growth cycle measurement of differing detrending methods, we also constructed the Australian growth cycle by: (i) deterministically detrending real GDP; and (ii) by implementing the Hodrick-Prescott filter.[18] Relative to the OC filter, both the deterministic detrending filter and HP filter yield: fewer turning points in the growth cycle; relatively longer low-rate phases; and sharper speed of movement in filtered output (Table 5).

Table 5. Features of the Australian Growth Cycle, 1959:3-2000:4

	Trend	**HP**	**OC**
Number of downturns	10	10	11
Number of upturns	10	9	10
Time spent in low-rate phase (percent)	43	43	42
Average duration of high-rate phase (quarters)	8.22	9.89	9.10
Average duration of low-rate phase (quarters)	7.10	7.22	6.10
Average amplitude of high-rate phase (percent change)	5.64	4.74	3.47
Average amplitude of low-rate phase (percent change)	-4.76	-4.88	-3.63

Notes: Trend denotes deterministically detrended GDP series; HP denotes the Hodrick-Prescott (1980) filtered GDP series; OC denotes the Ouliaris-Corbae (2002) filtered GDP series. For all filters, the Bry-Boschan growth cycle-dating algorithm (as described in Section IV) is used to determine turning points in the Australian growth cycle. For the growth cycle, turning points in output adjusted for its long-run trend (that is, filtered real GDP) are described as downturns and upturns, with periods between downturns and upturns (upturns and downturns) denoted as low-rate (high-rate) growth phases.

[17] In contrast, Bodman (1998) analyzed the first difference of the log of Australian GDP, and using turning points estimated by a regime-switching model found some evidence of duration dependence in GDP contractions.

[18] We did not compare the turning points in the growth cycle generated by the Baxter-King filter, as it cannot generate estimates of the cycle at the end-points of a series.

E. Cyclical Relationship Between Output and Prices

To illustrate the effects of filtering on the cyclical properties of a given variable, we consider the cross-correlation of filtered output and a similarly-transformed price level series. Various studies, starting with Burns and Mitchell (1946), have examined this issue. Burns and Mitchell (1946, Table 22, p.101), considering a sample period from 1854-1933, found the U.S. wholesale price level to be procyclical based on reference cycle dates. However, employing the HP filter on post Second World War (postwar) U.S. data, Kydland and Prescott (1990) found the price level to be countercyclical. Using data on ten industrial countries, Backus and Kehoe (1992) found evidence in support of the contention that price fluctuations have changed from procyclical to countercyclical in the postwar period. In examining the cyclical behavior of Australian prices, we use in this paper the logarithm of the Australian GDP deflator (for the sample period 1959:3 to 2000:4) as our measure of the price level, and continue to use the logarithm of real Australian GDP as our measure of real output.[19]

Table 6 provides the standard deviation, skewness, and kurtosis of the price level series (the GDP deflator) for each filter, as well as the cross-correlation of the filtered price series with OC filtered output ($\tilde{x}^f$). We plot the filtered data for real output and prices employing the OC method in Figure 4. The relationship between real output and the price level is countercyclical for the entire sample period, with a significant correlation of -0.22.[20] This negative correlation suggests the Australian economy has experienced a predominance of supply-side shocks in the postwar period, which for a given level of aggregate demand, has shifted aggregate supply and equilibrium prices in the opposite direction.[21]

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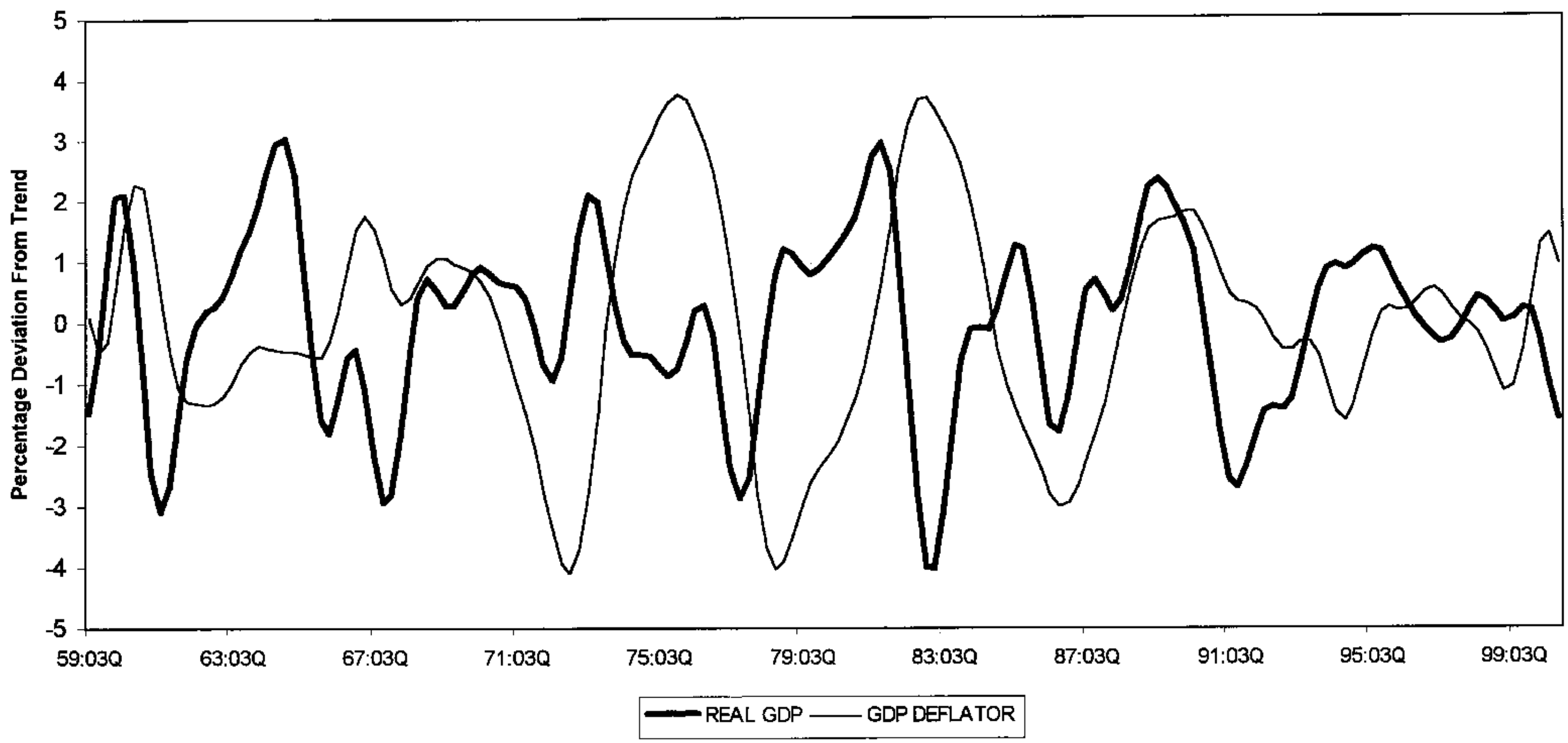
[19] While the literature (including this study) refers to the relationship between prices and output over the business cycle, the filtered series are (as noted above) deviations from their respective trends.

[20] The 5 percent critical value for the correlation of the Australian output and prices (0.15) was calculated as $1.96/T^{1/2}$, where T=166 is the number of observations.

[21] This result is a simple correlation, and is not conditioned on any other information. As pointed out by Cooley and Ohanian (1991), one can find a set of conditioning variables (lags of the variables in question and lags of other variables) such that the *conditional* correlations between prices and output may be positive. Judd and Trehan (1995) do exactly that, constructing a multivariate vector autoregressive model of prices, output and other macroeconomic variables, and find that for the United States there is a positive relation between prices and output, conditional on other macroeconomic variables (chiefly real money balances).

Figure 4. Australia: OC(6,32) Estimate of Real GDP and Price Level Cycles, 1959:3-2000:4



Notes: OC denotes Ouliaris-Corbae (2002) filtered real GDP and filtered price level.

Table 6. Summary Statistics for the Australian GDP Deflator, 1959:3-2000:4

	HP	**BK**	**OC**
Standard deviation	1.759	1.643	1.797
Skewness	-0.200	-0.403	-0.061
Kurtosis	1.365	0.626	0.270
Correlation with filtered output ($\tilde{x}^f$)	-0.147	-0.150	-0.220

Notes: HP denotes the Hodrick-Prescott (1980) filtered deflator; BK denotes the Baxter-King (1999) filtered deflator; OC denotes the Ouliaris-Corbae (2002) filtered deflator. The skewness measure is $\mu_3/(\mu_2)^{1.5}$ and the kurtosis measure is $\mu_4/(\mu_2)^2$, where μ_r is the r^{th} (central) moment. The skewness of a symmetrical distribution, such as the normal, is zero; similarly, the kurtosis of the normal distribution is 3. The 5 percent critical value for the correlation of Australian output and prices (filtered output and the price level) is 0.152, and was calculated as $1.96/T^{½}$ where T=166 is the number of observations.

Kydland and Prescott (1990), Cooley and Ohanian (1991), and Chadha and Prasad (1994) all find that there is countercyclical variation in the price level of the United States and other industrialized countries, especially in the postwar period. Consistent with those results, we also find that the cyclical components of Australian prices and output are negatively correlated. Our finding also accords with previous findings on the cross-correlation of the postwar cyclical components of Australian prices and output by Backus and Kehoe (1992) and Fisher, Otto and Voss (1996).

V. Conclusions

The relative mildness of economic fluctuations in many developed economies since the 1950s, in tandem with recent developments in time series analysis, has led to a renewed interest in growth cycles (cyclical movements in trend-adjusted output) in comparison with classical cycles (cyclical movements in trend-unadjusted output). In this study we have examined the key stylized facts of Australian business cycles over the period 1959-2000, and calculated a chronology for the classical cycle (involving expansions and contractions in the level of real output) and the growth cycle (involving alternating periods of above- and below-trend economic growth). In obtaining new measures of Australia's classical and growth cycles, we applied variants of the Bry and Boschan (1971) cycle-dating algorithm, and used a recently-developed frequency domain filter to estimate the Australian growth cycle.

In examining the stylized features of Australian business cycles, we have several key findings. First, Australian growth cycles are relatively symmetric in both duration and amplitude. This is unlike the Australian classical cycle, which exhibits long-lived expansions and much shorter-lived contractions, and much greater amplitude of output movement in expansions than contractions. Second, the probability of a contraction or expansion in real GDP ending was found to be independent of its duration; similarly, there was little evidence that the phases of the Australian growth cycle (real GDP adjusted for trend) maintained a fixed duration. Third, while there is evidence of a relationship between the severity of above-trend movements in real GDP and their duration, such a relationship is not present for below-trend movements in real GDP or for both expansions and contractions in real GDP. Accordingly, while there are some similarities in the ups and downs of Australian classical and growth cycles, no two business cycles are exactly alike. Fourth, over the last four decades, prices have moved counter-cyclically with output, which is suggestive of a predominance of shocks to aggregate supply affecting the Australian economy. Our analysis has yielded a number of useful empirical key features of Australian classical and growth cycles, and future work on theoretical business cycle models will need to take account of these stylized facts.

Dating of Classical Business Cycles Using the Bry and Boschan Algorithm

To determine the turning points (peaks and troughs) in quarterly real GDP, the original Bry and Boschan (1971) business cycle-dating algorithm has been adapted as follows.

Step 1: Make first pass at dating peaks and troughs

The algorithm picks an initial selection of peaks and troughs, where a peak is located at the highest point in the series using a window two quarters either side of that point, and vice versa for troughs.

Step 2: Enforce alternation of peaks and troughs

The algorithm checks that none of the peak dates and trough dates are shared.

Step 3: Censor dates

(i) The algorithm enforces the restriction that cycles (peak-to-peak and trough-to-trough) are at least 5 quarters long.

(ii) The algorithm censors the dates at the end of the series by eliminating turns within 2 quarters of both ends of the series, and by eliminating peaks (troughs) at both ends which are lower (higher) than values closer to the end.

(iii) The algorithm again checks the restriction that cycles (peak-to-peak and trough-to-trough) are at least 5 quarters long.

(iv) The algorithm eliminates phases whose duration is less than 2 quarters long.

Step 4: Statement of final turning points

The algorithm selects the final peak and trough dates.

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