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Business Cycle Asymmetry and Duration Dependence: An International Perspective

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1. INTRODUCTION

The business cycle behaviour of macroeconomic variables has long been of interest to economists, and some attention has recently focused on two aspects of this behaviour – the 'stylised facts' of cyclical asymmetry and duration dependence. Cyclical asymmetry is where the economy behaves differently over the expansion and recession phases of the business cycle and, consequently, cannot be captured by linear models. There has thus been much interest in non-linear specifications that can distinguish between these phases and which are sufficiently flexible to allow different relationships to apply over them. Examples of such specifications are the threshold and smooth transition models (see, for example, Teräsvirta and Anderson, 1992) and the various Markov-switching regime models, all of which stem from the original model proposed by Hamilton (1989). Duration dependence, on the other hand, concerns the question of whether, for example, the probability of a cyclical expansion is dependent on how long the expansion has been running, or whether business cycle lengths tend to cluster around a particular duration (see, for example, Diebold and Rudebusch, 1990, and Diebold, Rudebusch and Sichel, 1993). Duration dependence and switching regime models are related: Hamilton (1989) assumed that the state transition probabilities in his regime switching model were duration independent so that, for example, after a long expansion the economy was no more likely to switch to the recession regime than after a short expansion. Models such as Kim and Nelson (1998) attempt to marry these two features.

Much of the empirical work using these models is either country specific or restricts analysis to just post-World War II data. Recently, however, there have become available much longer and wider macroeconomic data sets. Consequently, it is now possible to "turn business cycle theories loose on perhaps the greatest macroeconomic laboratory available: the extant record of macroeconomic historical statistics for a broad cross-section of countries since the late 19th century" (Basu and Taylor, 1999, pp. 45-6). Focusing attention on long runs of macroeconomic data has its problems, of course, for it becomes difficult to maintain the assumption of a stable model structure in the presence of the impacts of two world and various civil wars, three monetary regimes, oil price shocks, etc. This is important not just for examining the stylised facts of business cycles but also for deciding upon which methods to use to obtain the cyclical components of the time series under investigation, as such components are the necessary data on which most analyses are based.

Consequently, we focus attention in this paper on nonparametric techniques for extracting cyclical components and for modelling and testing asymmetry and duration dependence. Section 2 thus introduces the data set used for the exercises and discusses the technique employed to obtain cyclical components. Sections 3 and 4 set out the hypotheses concerning cyclical asymmetry and duration dependence that are of interest and the statistics that are used to test them. Results are presented in Section 5 with conclusions following in the final section.

2. THE DATA AND THE CONSTRUCTION OF CYCLICAL COMPONENTS

We focus attention on the 22 countries for which output per capita is available over a reasonably long time span. These are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, the Netherlands, Italy, New Zealand, Norway, Sweden, the U.K. and the U.S., all with data beginning in 1870, Japan, with start date 1885, Switzerland (1899), Argentina, Brazil and Spain (all 1900), Taiwan (1903), and Korea (1911). This data set has been used by Mills and Crafts (2000) to study trend growth patterns and issues of convergence within the context of the endogenous growth debate, and this reference may be consulted for extensive evidence on the time series properties of the series under consideration.

As stated in the Introduction, we employ a nonparametric approach to estimating the cyclical component of (the logarithm) of output per capita. The basic idea is to use a linear filter (a two-sided moving average) that is explicitly designed to capture movements in a time series that correspond to business cycle fluctuations. Baxter and King (1995) develop a band-pass filter that extracts such components while removing components at higher (i.e., trend) and lower (irregular) frequencies. For annual data, the filter that passes components with frequencies of between two and eight years is defined as

$$y_t^* = 0.7741y_t - 0.2010(y_{t-1} + y_{t+1}) - 0.1351(y_{t-2} + y_{t+2}) - 0.0501(y_{t-3} + y_{t+3}) \qquad (1)$$

where y_t is the logarithm of output per capita in year t and y_t^* is the cyclical component to be used in further analyses. Such a cyclical component will induce stationarity in series that either contain quadratic deterministic trends or stochastic trends that make y_t integrated of order 2. The cycle y_t^* will have zero mean but will typically be autocorrelated.

Studies that have used this filter to extract cyclical components include, in the historical context, Basu and Taylor (1999) and Mills (2000), and, using its quarterly variant, Stock and Watson (1998). The band-pass filter is close to being the ideal filter for passing only components with business cycle frequencies, its sub-optimality only being a consequence of having to use a finite, rather than an infinite, time series for y_t. The more widely used Hodrick and Prescott (1997) filter has a tendency to pass high-frequency noise outside the business cycle frequency band but judicious setting of its ‘smoothing parameter’, which penalises variation in trend, enables the Hodrick-Prescott filter to closely approximate the band-pass. (Baxter and King show that setting the smoothing parameter to about 10 produces a Hodrick-Prescott filter that is very similar to the band-pass for annual data.)

3. Cyclical Asymmetry: Steepness and Deepness

Sichel (1993) defines an asymmetric business cycle as one in which some phase of the cycle is different from the mirror image of the opposite phase, so that contractions might be steeper, on average, than expansions, an observation first made, it would appear, by Keynes (1936). Sichel distinguishes two types of asymmetry that could exist either separately or simultaneously. The first type – which is certainly the most popular characterisation – occurs when contractions are indeed steeper than expansions. We refer to this as *steepness* asymmetry. The second type occurs when troughs are deeper than peaks are tall – this is referred to as *deepness* asymmetry. Steepness asymmetry thus pertains to relative slopes and compares mirror images across imaginary vertical axes placed at peaks and troughs of the cyclical component y_t^*. Deepness asymmetry, on the other hand, pertains to relative *levels* and compares mirror images across a horizontal axis (see Sichel, 1993, for graphical illustrations). Deep cycles may be generated by a model with asymmetric price adjustment, in which positive nominal demand shocks will have a relatively small positive effect on output, whereas negative shocks will have larger negative effects. Steepness asymmetry can be generated by models with asymmetric costs of upward and downward adjustment: for example, industry exit costs might be less than entry costs, so that production can fall rapidly, but expand more slowly.

If a cyclical component y_t^* exhibits deepness, then it should exhibit negative skewness, as it should have fewer observations below its mean (of zero) than above it, but the average deviation of the observations below zero should exceed the average deviation of observations above it. The usual moment measure coefficient of skewness is defined as

$$S = m_3 \big/ m_2^{3/2} \tag{2}$$

where m_j is the *j*th moment of y_t^*. This is well known to have a variance of $6/T$ when the sample size T is large and when y_t^* is normally and independently distributed. Unfortunately, neither of these assumptions will necessarily hold here. For non-normal data, the appropriate variance of S is

$$\sigma_S^2 = T^{-1}\left(\frac{m_6}{m_2^3} - 6K + 9 + \frac{S^2}{4}(9K+35) - \frac{3m_5 m_3}{m_2^4}\right) \tag{3}$$

where $K = m_4 / m_2^2$ is the usual moment measure of kurtosis (see Stuart and Ord, 1987, Exercise 10.26). To incorporate possible dependence in the form of a general autocorrelation structure, this variance can be adjusted by using a Newey-West (1987) type correction of the form

$$\sigma_S^2(\ell) = \sigma_S^2\left(1 + \frac{2}{T}\sum_{j=1}^{\ell} \omega_j \rho_j\right) \tag{4}$$

where ρ_j is the jth autocorrelation of $(y_t^*)^3 / m_2^{3/2}$ and the weights are such that $\omega_j = 1 - j/(\ell+1)$ with $\ell = [4(T/100)^{2/9}]$. Thus $Z_S = S/\sigma_S(\ell)$ will be asymptotically standard normal and significantly negative values of this statistic will indicate deepness. Sichel (1993) makes a similar Newey-West adjustment but does not adjust the variance for non-normality.

An alternative test, which is distribution free and does not require a known median, is that proposed by Mira (1999). This is based on the order statistics $y_{(1)}^* \leq y_{(2)}^* \leq \ldots \leq y_{(T)}^*$ obtained by ordering y_t^* by size, and attention is focused on $g = \bar{y}^* - y_{med}^*$, where y_{med}^* is the median of y_t^*. Mira shows that $Z_g = g/\sigma_g$ is asymptotically standard normal, where

$$\sigma_g^2 = \left(4\hat{\sigma}^2 + D^2 - 4D \cdot E\right)/4T$$

$$\hat{\sigma}^2 = m_2/(T-1)$$

$$D = T^{1/5}\left(y^*_{[0.5(T+T^{0.8})]} - y^*_{[0.5(T-T^{0.8}+2)]}\right)$$

and

$$E = \bar{y}^* - \frac{2}{T}\sum_{t=1}^{T} y_t^* I\left(y_t^* \leq y_{med}\right)$$

Mira shows that his test is often asymptotically relatively more efficient than the moment test for skewness for a variety of distributions, so that this test is worth considering as an alternative to Z_S.

If y_t^* exhibits steepness, then its *first differences* should exhibit negative skewness, i.e., sharp decreases in the series should be larger, but less frequent, than more modest increases in the series. Hence tests for steepness can be computed as above by using Δy_t^* rather than y_t^* in the computations.

4. DURATION DEPENDENCE OF CYCLES

Duration dependence is related to symmetry in the sense that, if business cycles were perfectly symmetric, then there would be what Diebold and Rudebusch (1990) define as *deterministic strong periodicity*. In general, however, Diebold and Rudebusch define *stochastic weak (peak-to-peak) periodicity (of period* T*)* if for every y_t^* that is a peak of the series, $y_{t+\tau}^*$ is also a peak, where τ is a random variable with mean T and variance σ_τ^2. This implies that there is a tight distribution of observed peak-to-peak durations, τ, around the mean period T, so that σ_τ^2 is small. Since a cycle of duration $\tau < \mathrm{T}$ is less likely to end than a cycle of duration $\tau > \mathrm{T}$, then periodic cycles are characterised by the probability of a peak increasing with the length of the ongoing cycle. Non-periodic cycles, on the other hand, have no particular interval after which they are more likely to end, so that their turning points are not positively related to the age of the cycle. Diebold and Rudebusch argue that the exponential distribution provides a metric for the extent of periodicity. If cycle durations are independent, then the unconditional density of such durations, $f(\tau)$, is given by the exponential (or constant hazard) function

$$f(\tau) = \lambda \exp(-\lambda(\tau - t_0)), \qquad \tau \geq t_0 \tag{5}$$

where λ is the constant probability of termination and t_0 is the minimum possible duration – the density of durations is therefore monotonically declining. If there are N business cycles with durations $x_1 \leq x_2 \leq \ldots \leq x_N$, the hypothesis that the duration random variable τ has the exponential density function (5) can be tested using the Shapiro and Wilk (1972) statistic

$$W = \frac{(\bar{x} - x_1)^2}{(N-1)\hat{\sigma}^2}$$

where $\bar{x} = N^{-1}\sum_{i=1}^{N} x_i$ and $\hat{\sigma}^2 = N^{-1}\sum_{i=1}^{N}(x_i - \bar{x})^2$. The distribution of W is invariant to the true values of λ and t_0 and its exact finite-sample critical values are tabulated by Shapiro and Wilk.

A modified W tests exponentiality conditional on an assumed known minimum duration. Denoting this minimum duration as t_0, this new statistic is defined as

$$W^* = \frac{A^2}{N\left((N+1)B - A^2\right)}$$

where $A = \sum_{i=1}^{N}(x_i - t_0) = N(\bar{x} - t_0)$ and $B = \sum_{i=1}^{N}(x_i - t_0)^2 = N(\hat{s}^2 + (\bar{x} - t_0)^2)$. W^* has the same distribution for a sample of size N as W has for a sample of size $N+1$, so that the same Shapiro and Wilk table of finite sample critical values can be used.

Brain and Shapiro (1983) provide another class of nonparametric tests for the exponential distribution, in which they define the normalised spacings between the ordered durations to be

$$X_i = (N - i + 1)(x_i - x_{i-1}), \qquad i = 2, \ldots, N$$

With $\bar{i} = i - (N/2)$ and $\bar{X}_i = X_i - \bar{X}$, the hypothesis of exponentiality can be tested by

$$Z_1 = \frac{\sum_{i=1}^{N-1}(i - N/2)(X_{i+1} - \bar{X})}{\sum_{i=1}^{N-1} Y_{i+1}\left(\sum_{i=1}^{N-1}(i - N/2)^2 / N(N-1)\right)^{1/2}}$$

Z_1 is asymptotically distributed as standard normal, which it quickly approaches even in quite small samples. An assumed known minimum duration of t_0 can be incorporated by including a new observation $X_1 = N(x_1 - t_0)$ into the calculations (and adjusting the summations accordingly): we refer to this statistic as Z_1^*.

Finally, Mudambi and Taylor (1995) suggest using the statistic

$$Z_2 = N^{1/2}\left(\left(\bar{Q}/s_Q\right) - 1\right)$$

where $\bar{Q}$ and s_Q are the mean and standard deviation of the transformed durations $Q_i = x_i - t_0$. Again, Z_2 is asymptotically standard normal.

5. EMPIRICAL RESULTS

The two skewness statistics were calculated for both y_t^*, to test deepness, and Δy_t^*, to test steepness. Because we are interested in asymmetries induced by economic behaviour, the statistics should be calculated on data that reflect intrinsic macroeconomic forces rather than special factors. In other words, we want to uncover the systematic mechanism of business cycles, rather than accidental and episodic crises associated with, for example, wars, bad harvests and oil price hikes. For each series, we thus produce two sets of statistics: the first using the complete sample of observations, the second using a trimmed sample which removes those outliers whose absolute value is in excess of three standard deviations. These statistics are reported in Tables 1 and 2.

Table 1

Deepness Statistics

	y_t^*, Complete sample		y_t^*, Trimmed sample	
	Z_S	Z_g	Z_S	Z_g
Argentina	-1.92**	-0.55	-1.52*	-0.39
Australia	-0.54	-1.49*	-1.60*	-1.70**
Austria	-0.74	-0.75	0.61	-0.37
Belgium	-1.77**	0.26	0.61	1.15
Brazil	1.11	0.38	1.11	0.38
Canada	-1.35*	-0.11	0.76	0.33
Denmark	-0.54	-0.26	-0.22	0.48
Finland	-1.88**	-1.23	0.28	-0.66
France	-2.22***	-0.43	1.51	1.03
Germany	-1.00	-0.51	-1.18	0.00
Holland	-6.48***	-1.40*	0.02	-0.01
Italy	-2.37***	-0.07	1.32	1.15
Japan	-0.88	0.03	-0.08	0.42
Korea	-0.60	-0.09	-0.27	0.09
Norway	-1.56*	0.40	0.97	1.75
New Zealand	1.12	0.97	1.12	0.97
Spain	-0.33	-0.49	-0.93	-0.19
Sweden	-2.15***	-0.70	-0.70	0.06
Switzerland	-2.05***	-0.59	0.76	-0.01
Taiwan	-0.08	0.69	0.90	1.20
U.K.	-0.48	-0.65	-0.31	-0.64
U.S.	0.87	-1.58*	-0.13	-1.94**

*, **, *** denotes significance at the 10%, 5% and 1% levels respectively.

Table 2

Steepness Statistics

	Δy_t^*, Complete sample		Δy_t^*, Trimmed sample	
	Z_S	Z_g	Z_S	Z_g
Argentina	-0.32	-1.14	-0.15	-1.03
Australia	0.11	-0.20	-0.05	-0.44
Austria	-7.12***	-0.32	0.12	0.38
Belgium	-0.46	0.04	1.04	0.40
Brazil	0.10	-0.54	0.10	-0.54
Canada	-0.97	-1.36*	-0.64	-1.09
Denmark	-1.34*	-0.27	-0.40	0.39
Finland	0.26	-0.50	0.65	-0.12
France	0.84	0.12	1.98	0.57
Germany	-2.59***	-0.31	-2.78***	-0.22
Holland	0.25	-0.01	3.55	0.58
Italy	0.09	-0.14	0.94	0.43
Japan	-4.86***	-0.22	1.91	0.97
Korea	-7.01***	-0.61	0.97	0.34
Norway	-0.52	-1.19	1.12	-0.67
New Zealand	-1.33*	0.32	-1.33*	0.32
Spain	-1.91**	-0.71	-1.29*	-0.31
Sweden	-1.34*	-0.12	-0.23	0.45
Switzerland	0.76	-0.01	0.76	0.16
Taiwan	-1.89**	0.27	-1.00	0.56
U.K.	-1.25	-0.76	-0.91	-0.64
U.S.	-1.53*	-0.01	-1.50*	-0.10

*, **, *** denotes significance at the 10%, 5% and 1% levels respectively.

From the complete sample statistics for deepness, eight Z_S statistics are significantly negative at the 5% level, but once outliers are removed (these being almost always a consequence of wars), there is virtually no remaining evidence of deepness. Mira's Z_g statistics show little evidence of deepness in either the complete or trimmed samples, although they do find some evidence for it for the U.S., which the more conventional statistic fails to do! Similar patterns emerge for the steepness statistics reported in Table 2, with only Germany exhibiting 'Z_S steepness' after outlier trimming, and no country exhibiting 'Z_g steepness'. We are thus bound to conclude from these tables that there appears to be little international evidence to support these forms of business cycle asymmetry. This conclusion may, however, be tempered somewhat by our unavoidable use of annual, rather than quarterly or monthly, data, which could mean that more complicated patterns of cyclical asymmetry remain uncovered. On the other hand, Sichel (1993) finds no evidence of asymmetry in quarterly post-war U.S. real output, although there does appear to both deepness and steepness in industrial production and unemployment.

Four sets of duration statistics are presented for peak-to-peak cycles in Table 3 and trough-to-trough cycles in Table 4 (Z_1^* statistics are not reported as they were identical to Z_1 using $t_0 = 2$). Note that such cycles are computed from the estimated y_t^* series and are not based upon any chronologically determined business cycle dating. Again, duration statistics could be influenced by large, episodic exogenous shocks, but since there is no clear information as to the size or direction of any bias, we prefer to use the complete samples of data. (Because of the difficulties in interpreting expansion and contraction (half-cycle) durations pointed out by Mudambi and Taylor, 1991, we focus only on complete cycle durations).

In contrast to steepness and deepness, there is more evidence to support duration dependence. The two sets of statistics provide similar evidence of duration dependence and there are more cases of trough-to-trough duration dependence than peak-to-peak. Argentina, Australia, Brazil, Canada, Finland, France, Holland, Korea, Taiwan and the U.S. show no evidence at the 5% level of duration dependence, whereas Austria, Denmark, Japan, Sweden, Switzerland and the U.K. exhibit strong evidence of both peak-to-peak and trough-to-trough dependence.

These tables also provide evidence on the mean length of durations and their variability. The peak-to-peak mean duration of all countries is 3.63 years, which is almost identical to the trough-to-trough mean duration of 3.61 years. There is slightly more variability in peak-to-peak durations, with a mean standard deviation of 1.39 compared to 1.33 for trough-to-trough durations.

Table 3

Duration Statistics: Peak-to-Peak

	N	Mean	St.Dev.	W	W^*	Z_1	Z_2
Argentina	26	3.31	1.05	0.0672*	0.0564	-0.72	1.25
Australia	34	3.47	1.26	0.0438	0.0385	-0.80	0.97
Austria	30	3.97	1.13	0.1120***	0.0919***	-3.14***	4.06***
Belgium	30	3.87	1.80	0.0399	0.0348	0.36	0.22
Brazil	24	3.67	1.58	0.0528	0.0444	0.00	0.27
Canada	33	3.48	1.23	0.0486*	0.0425	-1.12	1.20
Denmark	33	3.45	0.97	0.0745***	0.0637***	-2.62***	2.86***
Finland	33	3.58	1.39	0.0425	0.0374	-1.10	0.76
France	32	3.59	1.52	0.0377	0.0332	0.09	0.27
Germany	30	3.90	1.49	0.0597**	0.0512	-1.13	1.49
Holland	35	3.29	1.58	0.0206	0.0185	1.67*	-1.11
Italy	34	3.44	1.85	0.0197	0.0176	2.37**	-1.28
Japan	26	3.88	1.28	0.0945***	0.0776**	-1.77*	2.44**
Korea	19	3.84	1.57	0.0849	0.0675	-0.45	0.75
Norway	32	3.53	1.44	0.0391	0.0343	0.05	0.37
New Zealand	35	3.31	1.02	0.0515**	0.0451*	-1.38	1.69*
Spain	34	3.44	1.24	0.0438	0.0385	-1.07	0.97
Sweden	31	3.81	1.17	0.0853***	0.0718***	-2.56***	3.05***
Switzerland	22	4.00	1.35	0.1155***	0.0915**	-1.72*	2.28**
Taiwan	21	3.57	1.40	0.0696	0.0568	-0.33	0.57
U.K.	25	4.64	1.96	0.0824**	0.0681*	-1.32	1.75*
U.S.	33	3.42	1.23	0.0449	0.0394	-0.89	0.93

*, **, *** denotes significance at the 10%, 5% and 1% levels respectively.

Table 4

Duration Statistics: Trough-to-Trough

	N	Mean	St.Dev.	W	W^*	Z_1	Z_2
Argentina	26	3.35	1.23	0.0517	0.0440	-0.04	0.48
Australia	34	3.41	1.35	0.0351	0.0311	-0.19	0.26
Austria	31	3.81	1.35	0.0635**	0.0545*	-1.99**	1.87*
Belgium	31	3.81	1.40	0.0592**	0.0510*	-1.37	1.61
Brazil	23	3.70	1.92	0.0389	0.0329	1.04	-0.55
Canada	33	3.39	1.20	0.0450	0.0395	-0.81	0.94
Denmark	34	3.47	0.99	0.0707***	0.0608***	-2.79***	2.81***
Finland	33	3.52	1.37	0.0405	0.0357	-0.87	0.60
France	33	3.58	1.35	0.0455	0.0399	-0.56	0.98
Germany	30	3.83	1.46	0.0579*	0.0497	-1.40	1.38
Holland	36	3.28	1.41	0.0250	0.0224	1.32	-0.55
Italy	34	3.44	1.67	0.0239	0.0214	1.94*	-0.81
Japan	26	3.81	1.33	0.0803**	0.0667*	-1.76*	1.85*
Korea	20	3.85	1.46	0.0936*	0.0744	-0.91	1.19
Norway	33	3.61	1.30	0.0509*	0.0444	-1.14	1.37
New Zealand	35	3.29	1.07	0.0448*	0.0394	-0.95	1.17
Spain	34	3.32	0.91	0.0678***	0.0584**	-2.85***	2.63***
Sweden	32	3.75	1.08	0.0906***	0.0762***	-2.94***	3.53***
Switzerland	22	4.00	1.20	0.1463***	0.1131***	-2.22**	3.16***
Taiwan	21	3.86	1.49	0.0853*	0.0688	-0.92	1.12
U.K.	25	4.44	1.36	0.1463***	0.1148***	-2.99***	3.99***
U.S.	33	3.55	1.39	0.0408	0.0359	-0.89	0.62

*, **, *** denotes significance at the 10%, 5% and 1% levels respectively.

The U.K. has the longest mean duration, 4.64 years peak-to-peak and 4.44 years trough-to-trough, both of which are considerably longer than the next country, Switzerland, which has a mean duration of 4 years in both cases. The minimum mean duration is around 3.3 years, with several countries clustering around this value.

6. CONCLUSIONS

The results in this paper focus on long-run international evidence on whether the cyclical component of output per capita contains both asymmetries and duration dependence. Because we are analysing long runs of output data generated from a variety of regimes and historical episodes, so that the assumption of a stable model structure is unlikely to be tenable, we prefer to use nonparametric techniques for both extracting the cyclical component and testing for the presence of these features. Once outliers, primarily associated with wars, are omitted, there is little international evidence of asymmetry, at least of the deepness and steepness varieties introduced by Sichel (1993). There is considerably more evidence of duration dependence, which is detected in the majority of countries using a variety of nonparametric tests. There is thus widespread evidence against the ‘Monte Carlo’ cycle hypothesis that cyclical patterns occur simply by chance, so that the probability of reversal, say, occuring at time *t* is a constant, independent of the length of time elapsed since the last turning point (see, for example, McCulloch, 1975). Business cycles durations do appear to cluster around certain values, with the average duration being about 3.6 years.

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