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An International Perspective on Business Cycle Asymmetry: Evidence from Non-parametric Analysis

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Abstract: A cross-country comparison of business cycle asymmetry is conducted. The present analysis extends the existing literature in two ways. First, the 152 economies examined allows a larger cross-country comparison than presented in previous studies. Second, a new non-parametric test is employed which, unlike the typically applied test of asymmetry, is robust to outliers. The results obtained show asymmetric behaviour over the course of the business cycle to exist for a large number of economies. The implications of these findings for the implementation of economic policy and the specification of econometric models are noted.

Key words: Business cycles, asymmetry, triples test, cross-country comparison

INTRODUCTION

Interest in the possibility of the business cycle displaying asymmetric behaviour has a long history in economics. Following the early studies of Mitchell[1], Keynes[2] and Burns and Mitchell[3], it has typically been suggested that asymmetry exists in the form of recessionary periods being shorter and more volatile than expansionary periods. More recently, formal tests have been employed to evaluate this proposition. A feature of this recent literature is the examination of cyclical asymmetry via application of Sichel's[4] moment-based tests. Following this approach, a detrending filter is applied to data to derive the underlying cyclical component of a time series, before Sichel's tests are employed[5-7]. In the present paper, this approach to examining business cycle asymmetry is extended in two ways. First, a much larger range of economies is examined than has previously been considered. In the present paper, national output is examined for 152 economies to provide a more complete analysis of asymmetry at an international level. Second, a non-parametric test recently introduced to the economics literature by Verbrugge[8] is employed to overcome noted problems with the moment-based tests of Sichel[4]. In particular, Mills[7] has noted that the results obtained from application of Sichel's[4] tests can be biased by the presence of outliers in data. Consequently, when considering to national output for 22 OECD economies, Mills[7] applies the tests to a trimmed sample with detected outliers removed. In contrast, the non-parametric Triples test of Randles *et al*.[9] applied here has been found to be both robust to outliers and possess high power[10]. Therefore the present application of an alternative test to a large sample of economies complements the recent analysis of Mills[7] in which an absence of cyclical asymmetry at an international level was noted using a longer run of data for a more limited number of economies. Should asymmetry be uncovered, it will have a number of obvious implications for economic analysis. If the sizes of expansionary peaks and recessionary troughs, or the speeds at which they are approached, differ this will clearly have consequences for the implementation and impact of economic policy. At another level, detection of asymmetry will have implications for the specification of econometric models (which are typically linear and symmetric in nature), the understanding of economic behaviour and may also aid in the comparison and evaluation of alternative economic theories.

MATERIALS AND METHODS

The data examined in this paper are annual observations on real, per capita GDP over the period 1970 to 2001. The data are obtained from the International Monetary Fund's World Economic Outlook and cover 28 'advanced' and 124 'developing and transition' economies.

Testing for cyclical asymmetry

Detrending: To examine whether cyclical asymmetry is present, the cyclical component of GDP has to be derived

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for each of the economies considered. Following the standard approach in the literature, the cyclical component of the natural logarithm of per capita GDP is derived via application of a filter. Therefore, denoting the natural logarithm of real, per capita GDP for economy $y_{i,t}$, the cyclical component of the series can be expressed as:

$$c_{i,t} = y_{i,t} - \tau_{i,t} \qquad (1)$$

where $\tau_{i,t}$ is the trend underlying $y_{i,t}$. Again, following the standard approach in the literature, the Hodrick-Prescott (HP)[11] filter is employed to derive $\tau_{i,t}$. Essentially, subtraction of the HP trend allows the data examined to be filtered to isolate movements corresponding to business cycle fluctuations. Although numerous detrending procedures exist[12,13] the HP filter has a number of attractive features and advantages over its rivals in the present context. In particular, because of its linear structure, the HP filter will not induce spurious asymmetry in the derived cyclical components. Using the above notation, the HP filter derives a smooth trend $\tau_{i,t}$ as the solution to the following convex minimisation problem:

$$\min \sum_{t=1}^{T} \left\{ (y_{i,t} - \tau_{i,t})^2 + \lambda [(1-L)^2 \tau_{i,t}]^2 \right\} \qquad (2)$$

where L is the lag operator and λ is the smoothing parameter. It can be seen from the structure of HP filter that the extreme values of $\lambda = \{0,\infty\}$ result in the derived trend equaling the original series $y_{i,t}$ and a linear trend, respectively. Previously, the choice of the appropriate value of λ to employ in practice for annual data has not been well defined. However, the recent research of Ravn and Uhlig[14] presents convincing arguments for the adoption of 6.25 as the optimal value of the smoothing parameter λ. It is this value that is adopted here.

The triples test: Despite their frequent application in the economics literature, the moment-based tests of Sichel[4] are problematic as they are sensitive to outliers. It is therefore possible to draw misleading inferences from the application of these tests as a result of a single or a small number of unusual observations. In contrast, the alternative non-parametric Triples test of Randles *et al.*[9] has been shown to be robust to outliers and also possess high power[9,10]. It is for these reasons that its recent introduction to economics literature by Verbrugge[8] is to be welcomed. The mechanics of the Triples test can be explained as follows.

Consider a sample containing N observations of the variable X. The sample contains $\binom{N}{3}$ combinations of possible 'triples', or sets of three observations. To analyse asymmetry, the distance between the middle value and the two extreme values can be examined for each triple. The triple (X_i, X_j, X_k), where $1 \le I \ne j \ne k \le N$, is therefore skewed to the right (left) if the middle observation is closer to the smallest (largest) value than the largest (smallest). Considering the function $f^*(X_i, X_j, X_k)$ defined as follows:

$$f^*(X_i,X_j,X_k) = \frac{1}{3}[\mathrm{sign}(X_i + X_j - 2X_k) + \mathrm{sign}(X_i + X_k - 2X_j) + \mathrm{sign}(X_j + X_k - 2X_i)] \qquad (3)$$

where:

$$\mathrm{sign}(x) = \begin{cases} 1 & x>0 \\ 0 & x=0 \\ -1 & x<0 \end{cases} \qquad (4)$$

the triple (X_i, X_j, X_k) is a right triple if $f^*(X_i, X_j, X_k) = 1/3$, while a left triple is given by $f^*(X_i, X_j, X_k) = -1/3$. Obviously $f^*(X_i, X_j, X_k) = 0$ corresponds to a triple which is not skewed. The test proposed by Randles *et al.*[9] is based upon the estimated value:

$$\hat{\eta} = \frac{1}{\binom{N}{3}} \sum_{i<j<k} f^*(X_i,X_j,X_k) \qquad (5)$$

The Triples test of the null of symmetry (H_0: $\eta \ne 0$) against the alternative of asymmetry (H_1: $\eta \ne 0$) is then given by:

$$T = \frac{\hat{\eta}}{\sigma^2_{\hat{\eta}}/N} \qquad (6)$$

The numerator of this expression is provided in equation (5). The denominator is derived as below:

$$\frac{\sigma^2_{\hat{\eta}}}{N} = \frac{1}{\binom{N}{3}} \sum_{c=1}^{3} \binom{3}{c} \binom{N-3}{3-c} \hat{\varsigma} c \qquad (7)$$

where:

$$\hat{\varsigma}1 = \frac{1}{N} \sum_{i=1}^{N} (f_1^*(X_i) - \hat{\eta})^2 \qquad (8)$$

$$f_1^*(X_i) = \frac{1}{\binom{N-1}{2}} \sum_{\substack{j<k \\ i\ne j, i\ne k}} \sum f^*(X_i,X_j,X_k) \qquad (9)$$

$$\hat{\varsigma}2 = \frac{1}{\binom{N}{2}} \sum_{j<k} \sum [f_2^*(X_j,X_k) - \hat{\eta}]^2 \qquad (10)$$

$$f_2^*(X_j,X_k) = \frac{1}{N-2} \sum_{\substack{i=1 \\ i\ne j\ne k}} \sum f^*(X_i,X_j,X_k) \qquad (11)$$

$$\hat{\varsigma}3 = \frac{1}{9} - \hat{\eta}^2$$

Randles *et al.*[9] showed that the test statistic T is asymptotically distributed as standard normal variate, with conventional critical values used to test the null hypothesis.

In the present study, the Triple test was employed to examine two possible forms of asymmetry. Application of the Triples test to the derived cyclical components ($c_{i,t}$) of GDP for each economy allows possible asymmetry to be uncovered in the form of a difference in the size of cyclical peaks and troughs. Therefore, if $\hat{\eta}$ is found to be positive and significant, this indicates that the business cycle peaks are higher than troughs are deep. In contrast, a negative and significant value of $\hat{\eta}$ indicates that the business cycle troughs are high. Asymmetry in the form of a difference in the size of peaks and troughs is referred to as deepness. However, asymmetry can also be considered in terms of the speeds at which peaks and troughs are approached. This possibility can be explored via application of the Triples test to the first differences of the cyclical components ($\Delta c_{i,t} = c_{i,t} - c_{i,t-1}$). Again, the significance and sign of $\hat{\eta}$ determines whether asymmetry is present and the form it takes. If $\hat{\eta}$ is found to be positive and significant, this indicates that peaks are approached more rapidly than troughs. Conversely, a significant, negative statistic indicates the opposite, with troughs approached more rapidly than peaks. To determine the significance of the calculated triples test statistics ($\hat{\eta}$), two-sided p-values are derived and reported. Evidence of asymmetry is noted $\hat{\eta}$ is found to be significant at the 10% level (p-value$\leq$0.1).

RESULTS AND DISCUSSION

Considering the results for the advanced economies, evidence of deepness is found for China (Hong Kong), Germany, Japan and Norway, although in the case of Germany significance is marginal. For these economies, the calculated measure of asymmetry ($\hat{\eta}$) is negative for China, but positive for the other three economies. This indicates that while business cycle troughs are deeper than peaks are high for China, the reverse is true for Germany, Japan and Norway. From inspection of the results in Table 1, it can be seen that no other advanced economies display evidence of significant deepness. Turning to the results for steepness, significant evidence of steepness is uncovered for the following advanced economies: Austria, Israel and The Netherlands. For Austria and The Netherlands, the negative values of $\hat{\eta}$ indicate that business cycle troughs are approached more rapidly than peaks, while the converse is true for Israel. No other economies possess significant steepness (Table 2).

Table 1: Deepness and steepness tests for advanced economies

	Deepness		Steepness	
Series	$\hat{\eta}$	p-values	$\hat{\eta}$	p-values
AUL	-0.009	0.086	-0.015	0.655
AUS	0.050	0.156	-0.056	0.080
BEL	0.052	0.175	-0.018	0.678
CAN	-0.030	0.385	-0.051	0.169
CHK	-0.078	0.015	-0.041	0.238
DEN	-0.016	0.577	0.018	0.534
FIN	-0.006	0.856	-0.050	0.158
FRA	0.045	0.216	-0.034	0.390
GER	0.049	0.102	-0.049	0.118
GRE	0.015	0.668	-0.040	0.249
ICE	-0.032	0.311	0.023	0.514
IRE	-0.004	0.913	-0.028	0.449
ISR	0.043	0.310	0.063	0.080
ITA	0.043	0.257	0.022	0.594
JAP	0.096	0.002	0.009	0.824
KOR	-0.033	0.255	-0.055	0.223
LUX	0.001	0.976	-0.020	0.497
NE	0.006	0.865	-0.059	0.042
NZ	-0.027	0.450	-0.060	0.875
NOR	0.060	0.030	-0.040	0.305
POR	-0.005	0.883	-0.020	0.680
SIN	-0.001	0.981	-0.061	0.109
SPA	0.014	0.723	-0.018	0.624
SWE	-0.038	0.196	-0.041	0.287
SWI	0.044	0.194	-0.046	0.266
TAI	-0.004	0.908	-0.010	0.764
UK	0.040	0.169	-0.053	0.156
US	-0.060	0.875	-0.050	0.131

Considering the developing and transition economies, significant deepness is found for the following economies: Bolivia, The Dominican Republic, Egypt, Fiji, Guatemala, Jordan Madagascar, Nepal, Romania, Rwanda, St. Vincent and Grenadines and Turkey. However, it should be noted that the evidence for The Dominican Republic and Fiji is marginal. From inspection of sign of $\hat{\eta}$, it can be inferred that cyclical troughs are deeper than peaks are high for all of the above economies with the exception of Guatemala, Madagascar, St. Vincent and Grenadines and Turkey where peaks are larger than troughs. The complete set of results from the application of deepness tests to the developing and transition economies are contained in Table 2. The results for steepness indicate presence of asymmetry for Algeria, Angola, Bolivia, China (Mainland), Columbia, Congo republic, Costa Rica, Egypt, Haiti, Honduras, Indonesia, Madagascar, Malaysia, Philippines, Poland and Turkey. For each of these economies a negative value of $\hat{\eta}$ is observed indicating that troughs are approached more rapidly than peaks. This consistency in the form of asymmetry is interesting as it corresponds to the form of asymmetry considered in the early business cycle literature with sharp declines into recessionary periods. The complete set of results from the application of the Triples test of steepness to the developing and transition economies are presented in Table 3.

Table 2: Deepness tests for developing and transition economies

Series	$\hat{\eta}$	p-values	Series	$\hat{\eta}$	p-values	Series	$\hat{\eta}$	p-values	Series	$\hat{\eta}$	p-values
ALB	-0.027	0.544	DJI	-0.021	0.492	LIB	0.035	0.193	SAM	0.017	0.722
ALG	0.010	0.785	DOM	-0.007	0.856	M	0.092	0.002	SAO	0.020	0.642
ANG	-0.024	0.488	DOR	-0.054	0.105	MA	-0.009	0.838	SAU	-0.028	0.305
ANT	-0.029	0.373	ECU	-0.054	0.129	MAA	0.015	0.690	SEN	-0.020	0.509
ARG	-0.047	0.133	EGY	0.057	0.067	MAE	-0.023	0.597	SEY	0.042	0.223
BA	-0.048	0.143	ELS	0.053	0.172	MAI	0.011	0.735	SIE	0.014	0.601
BAH	-0.019	0.560	EQU	-0.039	0.267	MAL	0.034	0.364	SOL	0.023	0.559
BAN	0.000	0.995	ETH	-0.052	0.152	MAR	0.011	0.741	SOU	0.009	0.800
BAR	0.015	0.642	FIJ	-0.053	0.104	MAU	0.019	0.477	SRI	0.006	0.856
BE	-0.033	0.340	GAB	0.037	0.368	MEX	0.023	0.542	STI	-0.014	0.764
BEN	0.022	0.507	GAM	0.039	0.352	MON	0.005	0.911	STL	-0.031	0.343
BHU	0.007	0.840	GHA	-0.003	0.944	MOR	-0.062	0.117	STV	0.059	0.048
BOL	-0.041	0.076	GRN	-0.052	0.206	MOZ	-0.053	0.110	SUD	-0.017	0.649
BOT	-0.003	0.933	GU	0.069	0.006	MYA	0.003	0.915	SUR	0.016	0.620
BRA	-0.050	0.141	GUA	-0.016	0.738	NAM	-0.038	0.389	SWA	0.017	0.614
BUL	0.029	0.412	GUB	0.002	0.959	NEP	-0.067	0.025	SYR	-0.019	0.509
BUR	0.010	0.823	GUY	0.009	0.762	NET	0.012	0.738	TAN	-0.022	0.527
BUU	-0.004	0.904	HAI	0.052	0.236	NIC	0.024	0.558	THA	-0.004	0.896
CAM	0.022	0.532	HON	0.002	0.959	NGE	-0.025	0.524	TOG	-0.032	0.445
CAP	-0.029	0.339	HUN	-0.002	0.941	NGR	-0.023	0.567	TON	0.047	0.133
CEN	-0.027	0.407	IN	0.029	0.300	OMA	0.015	0.673	TRI	0.074	0.003
CHA	-0.015	0.710	IND	0.039	0.253	PAK	-0.009	0.842	TUN	-0.012	0.749
CHI	0.008	0.844	IRA	-0.034	0.240	PAN	0.054	0.130	TUR	0.054	0.072
CHN	-0.013	0.704	JAM	0.033	0.315	PAP	0.044	0.234	U	-0.037	0.249
COL	0.022	0.498	JOR	-0.076	0.006	PAR	0.050	0.171	UAE	0.017	0.658
COM	0.019	0.577	KEN	-0.002	0.952	PER	-0.027	0.452	URU	0.010	0.844
CON	0.026	0.329	KIR	0.015	0.759	PHI	0.008	0.839	VAN	-0.017	0.569
COR	0.018	0.544	KUW	0.042	0.236	POL	0.029	0.370	VEN	-0.006	0.828
COS	0.006	0.863	LAO	-0.030	0.367	QAT	-0.004	0.917	VIE	0.008	0.875
COT	-0.006	0.853	LEB	-0.024	0.515	ROM	-0.056	0.060	ZAM	0.003	0.935
CYP	0.009	0.864	LES	0.035	0.437	RWA	-0.078	0.062	ZIM	-0.008	0.825

Table 3: Steepness tests for developing and transition economies

Series	$\hat{\eta}$	p-values	Series	$\hat{\eta}$	p-values	Series	$\hat{\eta}$	p-values	Series	$\hat{\eta}$	p-values
ALB	-0.020	0.683	DJI	-0.023	0.644	LIB	-0.028	0.511	SAM	0.018	0.669
ALG	-0.072	0.015	DOM	-0.002	0.974	M	-0.094	0.045	SAO	0.009	0.854
ANG	-0.075	0.034	DOR	-0.059	0.102	MA	-0.021	0.624	SAU	-0.023	0.546
ANT	-0.047	0.237	ECU	-0.025	0.604	MAA	-0.079	0.050	SEN	-0.031	0.410
ARG	-0.040	0.206	EGY	-0.077	0.066	MAE	0.024	0.565	SEY	0.012	0.760
BA	-0.040	0.311	ELS	-0.077	0.051	MAI	0.045	0.204	SIE	-0.027	0.408
BAH	0.016	0.735	EQU	0.010	0.803	MAL	-0.024	0.613	SOL	0.032	0.413
BAN	0.000	0.999	ETH	0.010	0.806	MAR	-0.029	0.523	SOU	0.003	0.931
BAR	-0.020	0.617	FIJ	0.023	0.491	MAU	-0.006	0.910	SRI	-0.034	0.372
BE	0.022	0.547	GAB	-0.086	0.098	MEX	-0.037	0.224	STI	0.026	0.572
BEN	-0.035	0.509	GAM	-0.022	0.644	MON	-0.069	0.063	STL	0.023	0.539
BHU	0.001	0.985	GHA	-0.026	0.611	MOR	0.004	0.902	STV	0.036	0.307
BOL	-0.062	0.032	GRN	-0.037	0.496	MOZ	-0.046	0.307	SUD	0.005	0.915
BOT	0.045	0.275	GU	0.028	0.552	MYA	-0.071	0.108	SUR	-0.002	0.966
BRA	-0.062	0.034	GUA	0.028	0.560	NAM	-0.013	0.755	SWA	0.010	0.819
BUL	-0.025	0.512	GUB	-0.013	0.804	NEP	0.007	0.845	SYR	-0.025	0.424
BUR	0.022	0.601	GUY	-0.021	0.551	NET	-0.002	0.963	TAN	-0.014	0.661
BUU	-0.027	0.425	HAI	-0.068	0.047	NIC	0.007	0.897	THA	-0.061	0.146
CAM	-0.007	0.889	HON	-0.046	0.106	NGE	-0.036	0.331	TOG	-0.016	0.713
CAP	-0.044	0.266	HUN	-0.059	0.135	NGR	-0.007	0.823	TON	0.031	0.367
CEN	-0.020	0.541	IN	-0.022	0.624	OMA	-0.021	0.595	TRI	-0.034	0.369
CHA	-0.029	0.536	IND	-0.087	0.014	PAK	-0.032	0.482	TUN	-0.016	0.703
CHI	-0.065	0.077	IRA	-0.043	0.160	PAN	-0.007	0.863	TUR	-0.087	0.002
CHN	-0.022	0.580	JAM	-0.026	0.485	PAP	0.008	0.790	U	-0.022	0.521
COL	-0.069	0.032	JOR	0.001	0.974	PAR	-0.002	0.952	UAE	-0.006	0.885
COM	-0.013	0.717	KEN	-0.005	0.902	PER	-0.038	0.368	URU	-0.033	0.422
CON	-0.028	0.387	KIR	-0.036	0.481	PHI	-0.088	0.018	VAN	0.026	0.498
COR	0.064	0.071	KUW	-0.024	0.440	POL	-0.123	0.000	VEN	-0.045	0.221
COS	-0.064	0.056	LAO	0.003	0.950	QAT	-0.030	0.416	VIE	0.051	0.261
COT	0.018	0.673	LEB	-0.031	0.471	ROM	0.013	0.698	ZAM	0.004	0.916
CYP	-0.019	0.698	LES	-0.015	0.778	RWA	0.009	0.851	ZIM	-0.004	0.913

In this study business cycle asymmetry has been examined using a range of economies. In contrast to previous studies, a recently proposed non-parametric test has been employed which is robust to outliers. In a further development of the literature, a larger range of economies has been examined than has previously been considered. The results of the analysis have show asymmetry to exist in a number of different forms. The analysis has also shown developing and transitional economies to possess asymmetry with the relative sizes of peaks and troughs and the speeds at which they are approached found to differ. As the presence of asymmetry has implications for economic policy, the understanding of economic behaviour and the specification of econometric models, the present results illustrating the existence of asymmetry for a number of economies have clear implications.

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