Empirical Evidence of Asymmetries in Taiwan's Business Cycles: A Simple Note

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ABSTRACT

This paper adopts Clements and Krolzig's parametric tests to determine the asymmetric properties of Taiwan's business fluctuations. In particular, we investigate three types of asymmetry: deepness, steepness and sharpness. We find that although the non-deep property is overwhelmingly applicable to Taiwan's business cycle Clement and Krolzig's parametric tests strongly reject non-steepness. This evidence for steepness suggests that non-linear models are preferable to linear models in describing Taiwan's business cycles. Finally, the conclusion with regards to the sharpness property is inconclusive but it must be model-dependent.

1. INTRODUCTION

Studies reported in the literature on business cycle asymmetries are of both great importance and considerable interest. Their importance stems from the fact if the data really exhibit asymmetric features, then the success of economic models should be able to capture these features and replicate the data.[1] They are intensely interesting to econometrician whose chief objective is to devise more powerful and robust tests to detect any asymmetries in a time series.

By now, many types of asymmetries have been introduced in the literature. The *deepness* and *steepness* of a business cycle, for example, were discussed by Sichel (1993), while the asymmetry of *sharpness* was championed by McQueen and Thorley (1993).[2] Loosely speaking, we say a detrended time series exhibits deepness if it has negative skewness relative to the mean or the trend, i.e., the average deviation of the observations below the mean exceeds that of the observations above. Secondly, a time series exhibits steepness if, upon being differenced, the resultant distribution is asymmetric. Thirdly, when a time series is characterized by sharpness asymmetry, then troughs (peaks) are sharp and peaks (troughs) are more rounded.[3]

Empirically, ample evidence of asymmetry is found in U.S. business cycles. See, for example, Neftci (1984), Falk (1986), DeLong and Summers (1986), Sichel (1989, 1993, 1994), Rothman (1991), McQueen and Thorley (1993), Ramsey and Rothman (1996), Kim and Mittnik (1996), Verbrugge (1997), and Clements and Krolzig (2002), and so on. However, these researchers do not draw congruent conclusions with regards to the asymmetric properties in the U.S. key macroeconomic time series (see Clements and Krolzig, 2003, for a review). International evidence for asymmetries has also recently been reported in the literature. Readers are referred to Razzak (2001) and Belaire-Franch and Contreras (2003).

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[1] See Psaradakis and Sola (2003) for details as to at least four reasons why asymmetry is essential in economics.

[2] Formal definitions of these asymmetries are defined in Section 3.

[3] Ramsey and Rothman (1996) noted that steepness is an example of "longitudinal" asymmetry (asymmetry in the direction of a business cycle), and deepness and sharpness are examples of "transversal" asymmetry (orthogonal to the direction of a business cycle).

Deepness, steepness and sharpness asymmetries are associated with a detrended time series, but still other types of asymmetries are identified in the level data of a time series. Friedman (1969, 1993) suggests that recessions are periods when output is hit by large transitory shocks. Upon following through the trough, output enters a high-growth recovery phase, eventually returning to the trend. This is referred to as *Friedman-type asymmetry* in the literature.

One kind of analogous asymmetry is the *Hamilton-type asymmetry*. Hamilton (1989) suggests modeling business cycle asymmetry by allowing the growth rate of real output to be governed by an unobserved two-state variable, implying that the economy is either in a positive growth state (expansion) or in a negative growth state (contraction). One important implication of the Hamilton-type of asymmetry is that a recession has a permanent effect on the level of output, meaning that this asymmetry completely differs from the "peak-reversion" or "bounce-back effect" of the Friedman-type asymmetry. Kim and Murray (2002) have proposed an econometric model to examine both types of asymmetries as regards to the U.S. coincident index.

Research on Taiwan's business cycle has recently received great attention. Huang et al. (1998), Huang (1999), and Chen and Lin (2000), to cite a few examples, employ the Markov Switching Model to analyze the feature of Taiwan's business cycles. While these studies have focused on identifying Taiwan's turning points, they have ignored, for the most part, the asymmetric features of Taiwan's business cycles. For this reason, the motivation behind this paper is to examine the asymmetric features of Taiwan's business fluctuations. Our empirical results are most enlightening, especially as none of the previous research on Taiwan's output fluctuations (or business cycles) has taken a thorough look at the asymmetric features.[4] This paper, therefore, compensates for those shortcomings of previous literature.

Here, we employ Clements and Krolzig's (2003) parametric tests under the Markov Switching autoregressive model to check three asymmetries in Taiwan's business fluctuations. In terms of capabilities, the tests of Clements and Krolzig (2003) are able to detect asymmetries in the propagation mechanisms of shocks, or first moment asymmetries, while the typical non-parametric tests based on the coefficients of the skewness of a detrended series are unable to discriminate between first-moment asymmetries and asymmetries in shocks. In addition, their Monte Carlo results show that

[4] One exception is Chen (2002) who applies Kim and Murray's (2002) model to check whether the Friedman-type and Hamilton-type asymmetries exist or not in Taiwan business fluctuations.

they are reliable tests for business cycle asymmetries even though the underlying data generating process is different from the empirical model.

The organization of the paper is as follows. Section 2 briefly elaborates on the definition of several business cycle asymmetries. Section 3 introduces the methodology: Clements and Krolzig's (2003) parametric tests. Section 4 summarizes data description and the empirical test results, while Section 5 presents the conclusions that we draw in this paper.

2. BUSINESS CYCLE ASYMMETRY

In this section we briefly elaborate on the definition of several business cycle asymmetries. Readers are referred to Sichel (1993) and Clements and Krolzig (2003) for more details. Following Clements and Krolzig (2003), throughout the article, x_t refers to the detrended series and hence a stationary process. We assume that the nonstationarity can be removed by differencing. However, none of the propositions on asymmetries in MS-AR models that follow, nor the testing procedures, requires this method of detrending, and all remain valid whichever method is used. All that we require is that a MS-AR model can be estimated for the detrended series, however obtained. The sensitivity of the findings on asymmetries to the method of trend elimination requires further research.

Definition 1. *The process $\{x_t\}$ is said to be non-deep iff x_t is not skewed, therefore:*

$$E\left[(x_t - \mu_x)^3\right] = 0. \tag{1}$$

Definition 2. *The process $\{x_t\}$ is said to be non-steep iff Δx_t is not skewed, therefore:*

$$E\left[\Delta x_t^3\right] = 0. \tag{2}$$

Definition 3. *The process $\{x_t\}$ is said to be non-sharp iff the transition probabilities to and from the two outer regimes are identical, then:*

$$p_{m1} = p_{mM} \quad \text{and} \quad p_{1m} = p_{Mm}, \quad \forall m \neq 1, M, \quad \text{and} \quad p_{1M} = p_{M1}. \tag{3}$$

As shown in Clements and Krolzig (2003), in a two-regime model, non-sharpness implies that $p_{12} = p_{21}$. In a three-regime model, it is necessary that $p_{12} = p_{32}$, $p_{13} = p_{31}$, and $p_{21} = p_{23}$. What we also note from their corollary 1 is that a two-regime MS model is never steep. Moreover, non-steepness implies non-deepness and vice versa.

If definitions 1 to 3 were true, then we would claim that a time series is symmetry as shown in the upper panel of Figure 1. The middle panel of Figure 1 plots contractions which represent both deepness and sharpness. It is clear that such contractions are significantly deeper and sharper than the expansions. The lower panel of Figure 1 shows steepness asymmetry with gradual upward slopes during the expansions, and steep downward slopes during contractions.

3. CLEMENTA AND KROLZIG'S TESTS

Clements and Krolzig (2003) introduce the Wald-type tests of the asymmetry hypotheses under the Markov-Switching autoregressive model (hereafter the C-K tests). By design, they facilitate computation in that the model does not have to be estimated under the null.[5] Consider the Markov-Switching autoregressive model which follows:

$$x_t = \mu(s_t) + \sum_{j=1}^{p} \alpha_j x_{t-j} + u_t, \tag{4}$$

where $u_t|s_t \sim NID(0, \sigma^2)$ and $s_t \in \{1, \cdots, M\}$ is generated by a Markov chain. The transition probabilities are time-invariant, i.e., $p_{ij} = \Pr(s_{t+1} = j|s_t = i)$, with $\sum_{j=1}^{M} p_{ij} = 1, \forall j, j \in \{1, \cdots, M\}$. Clements and Krolzig (2003) label this model MSI(M)-AR(p). If the conditional variance σ^2 is also regime-dependent, then they label the model MSIH(M)-AR(p).[6] They consider the Wald (W) test of the hypothesis, i.e.:

[5] Testing the number of regimes under the Markov Switching Model is typically complicated on account of the presence of unidentified nuisance parameters under the null of linearity. Besides this, the scores associated with parameters of interest under the alternative may be identical at zeros. Readers are referred to Hansen (1992, 1996) for more details.

[6] In the terminology of Clements and Krolzig (2003), Hamilton's (1989) model is labeled MSM(M)-AR(p) because it is the conditional mean of the data that switches back and forth. If both the conditional mean and variance of a Markov-Switching model switch back and forth, then the model is labeled MSMH(M)-AR(p).

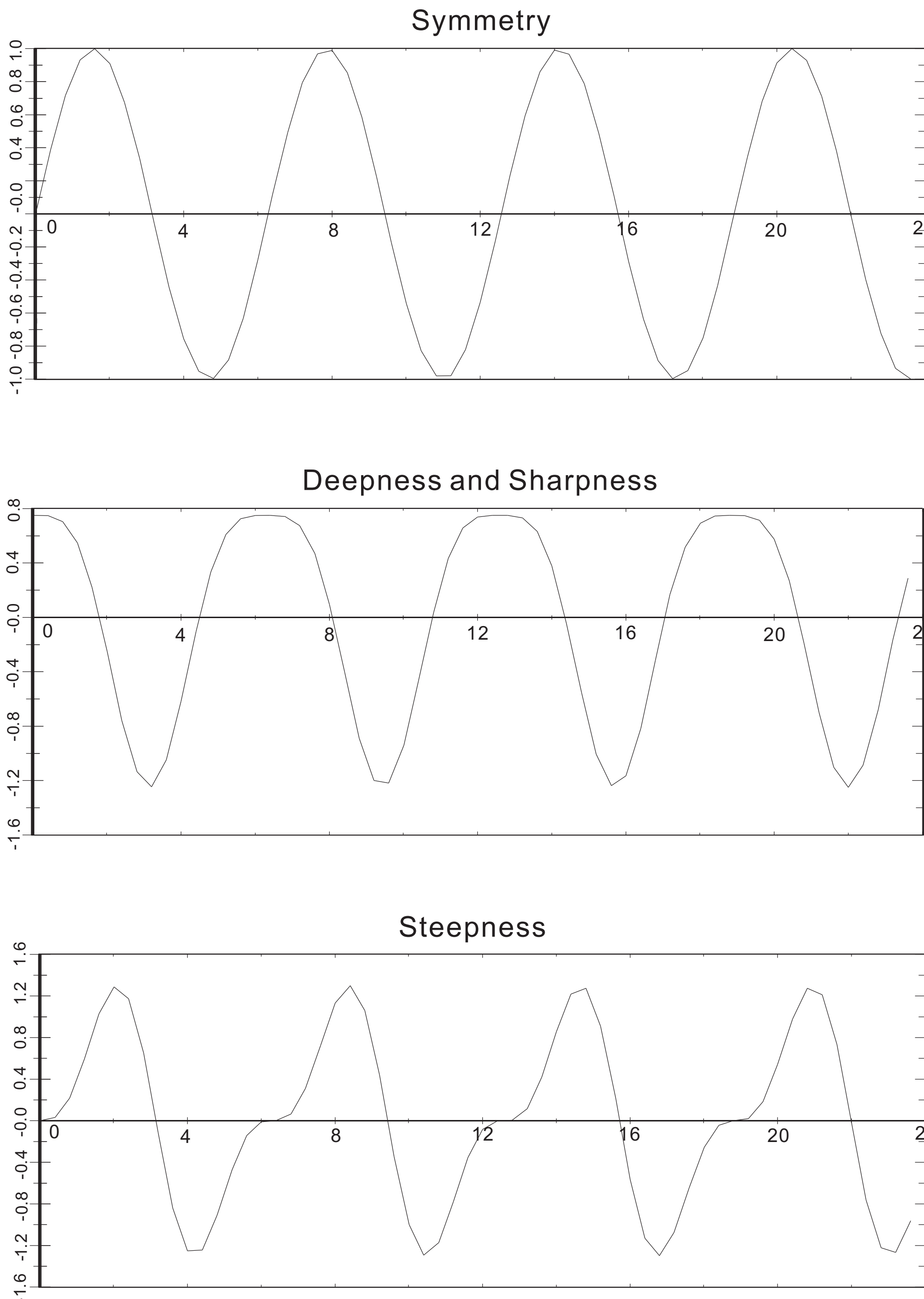

Figure 1 Time Series Plot of Symmetry, Deepness, Sharpness and Steepness

$$H_0:\phi(\lambda)=0 \quad \text{versus} \quad H_1:\phi(\lambda)\neq 0, \tag{5}$$

where $\lambda = (\mu_1, \cdots, \mu_M; \alpha_1, \cdots, \alpha_p, \sigma^2; \pi)$, $\phi = \mathbf{R}^n \to \mathbf{R}^r$ is a continuously differentiable function with rank r, and $r = \text{rk}(\frac{\partial\phi(\lambda)}{\partial\lambda'}) \leq \dim\lambda$.

Let $\tilde{\lambda}$ and $\hat{\lambda}$ denote the unrestricted and restricted maximum likelihood estimators of $\lambda = (\mu_1, \cdots, \mu_M; \alpha_1, \cdots, \alpha_p, \sigma^2; \pi)$, respectively. Then the Wald test statistic W is based on the unconditional estimator $\tilde{\lambda}$, which is asymptotically normal. That is:

$$\sqrt{T}\left(\tilde{\lambda}-\lambda\right) \xrightarrow{d} N\left(0, \Sigma_{\tilde{\lambda}}\right). \tag{6}$$

It follows that $\phi(\tilde{\lambda})$ is also normal for large samples.

$$\sqrt{T}\left[\phi\left(\tilde{\lambda}\right)-\phi(\lambda)\right] \xrightarrow{d} N\left(0, \left.\frac{\partial\phi(\lambda)}{\partial\lambda'}\right|_{\tilde{\lambda}} \Sigma_{\tilde{\lambda}} \left.\frac{\partial\phi(\lambda)'}{\partial\lambda'}\right|_{\tilde{\lambda}}\right). \tag{7}$$

If $H_0:\phi(\lambda)=0$ is true, and the variance-covariance matrix is invertible, then:

$$T\phi\left(\tilde{\lambda}\right)'\left[\left.\frac{\partial\phi(\lambda)}{\partial\lambda'}\right|_{\tilde{\lambda}} \widetilde{\Sigma}_{\tilde{\lambda}} \left.\frac{\partial\phi(\lambda)'}{\partial\lambda'}\right|_{\tilde{\lambda}}\right]'\phi\left(\tilde{\lambda}\right) \xrightarrow{d} \chi^2(r), \tag{8}$$

where $\widetilde{\Sigma}_{\tilde{\lambda}}$ is the consistent estimator of $\Sigma_{\tilde{\lambda}}$.

The Wald test for the null of *non-deepness* is based on:

$$\phi_D(\lambda) = \sum_{m=1}^{M} \bar{\xi}_m(\mu_m-\mu_x)^3, \tag{9}$$

where $\bar{\xi}_m$ is the ergodic probability of regime m, while $\mu_x = \sum_{m=1}^{M}\bar{\xi}_m\mu_m$ is the unconditional mean of x_t.

A Wald test for the null of *non-steepness* is based on

$$\phi_S(\lambda) = \sum_{i=1}^{M-1}\sum_{j=i+1}^{M}\left(\bar{\xi}_i p_{ij}-\bar{\xi}_j p_{ji}\right)\left(\mu_j-\mu_i\right)^3, \tag{10}$$

where the $\bar{\xi}_m$, p_{ij}, and μ_y are taken as fixed.

Finally, a Wald test for the null of *non-sharpness* can be expressed as

$$\phi_{TP}(\lambda) = \Phi\pi, \quad (11)$$

where the matrix Φ is defined such that $p_{m1} = p_{mM}$ and $p_{1m} = p_{Mm}$ for all $m \neq 1, M$, and $p_{1M} = p_{M1}$. The test statistics to evaluate non-deepness and non-steepness are asymptotically distributed as $\chi^2(1)$, whereas the test statistic to test the null of non-sharpness is asymptotically distributed as a $\chi^2(3)$ if $M = 3$, i.e., when testing the joint hypotheses $p_{12} = p_{32}$, $p_{13} = p_{31}$, and $p_{21} = p_{23}$. Readers are referred to Clements and Krolzig (2003) for more detailed descriptions of these tests.

4. EMPIRICAL RESULTS OF ASYMMETRIES

We select the real gross domestic product (GDP) to check its asymmetric properties. We choose this series since it is generally regarded as a good candidate to represent Taiwan's business cycle, see for example, Huang et al. (1998) and Huang (1999).[7] Those are the seasonally-adjusted quarterly data, with the sample period running from 1961:Q1 to 2000:Q4, which totals 160 observations. The data are taken from the AREMOS data bank.

In order to test the three types of asymmetries, we keep the number of regimes at fixed to three because a two-regime MS model always includes non-steepness and non-deepness. We consider four different Markov Switching models, namely, MSI, MSIH, MSM and MSMH, as introduced in the previous section. The maximum length of the autoregressive order is set at four. The model we finally choose is based on the minimum of the Schwartz Bayesian Criterion (SBC) and/or the Hannan-Quinn

[7] In a previous draft of this paper, we also check the asymmetric properties of fifteen key macroeconomic time series of Taiwan, such as real private consumption expenditure, real government expenditure, etc., by the triples test proposed by Randles et al. (1980). However, by design, the test is for data with identical and independent distribution (i.i.d.). As noted by an anonymous referee, our test results are probably unreliable because we do not make any serial corrections. Thus, we delete them in this draft, but those test results are available upon request.

Table 1 Model Selection

Models	SBC	HQ
MSI(3)-AR(0)	4.7105	4.5944
MSI(3)-AR(1)	4.3072	4.1790
MSI(3)-AR(2)	4.3082	4.1677
MSI(3)-AR(3)	4.3046	4.1517
MSI(3)-AR(4)	4.2441*	4.0787*
MSIH(3)-AR(0)	4.6868	4.5475
MSIH(3)-AR(1)	4.2086*	4.0570
MSIH(3)-AR(2)	4.2432	4.0792
MSIH(3)-AR(3)	4.3307	4.1543
MSIH(3)-AR(4)	4.2440	4.0550*
MSM(3)-AR(0)	4.7105	4.5944
MSM(3)-AR(1)	4.4037	4.2755
MSM(3)-AR(2)	4.3684	4.2279
MSM(3)-AR(3)	4.3296	4.1767
MSM(3)-AR(4)	4.3017*	4.1363*
MSMH(3)-AR(0)	4.6868	4.5475
MSMH(3)-AR(1)	4.3006	4.1490
MSMH(3)-AR(2)	4.3279	4.1640
MSMH(3)-AR(3)	4.3194	4.1430
MSMH(3)-AR(4)	4.2705*	4.0815*

* denotes the minimum value of the SBC or the HQ.

Information Criterion (HQ).[8] If the SBC and HQ do not give consistent results, based on the parsimonious principle, we then rely on the SBC criterion. Table 1 summarizes the SBC and HQ results for model selection.

In light of the SBC and HQ, we choose one model in each type of the Markov Switching autoregressive model. That is to say, we select four final models on the grounds that we want to check the *robustness* of the test results for the asymmetries.

[8] The formula for the Schwartz Bayesian Criterion and Hannan-Quinn Information Criterion are as follows:

$$\text{SBC} = \log\tilde{\sigma} + k\log(T)/T,$$
$$\text{HQ} = \log\tilde{\sigma} + 2k\log(\log(T))/T,$$

where $\tilde{\sigma}$ is the maximum likelihood estimate of σ.

Table 2 Clements and Krolzig's Test Results

Models	Non-Deepness	Non-Steepness	Non-Sharpness
MSI(3)-AR(4)	2.0211	7.4572*	27.2626*
	[0.1551]	[0.0063]	[0.0000]
MSIH(3)-AR(1)	1.6448	9.3498*	5.3015
	[0.1997]	[0.0022]	[0.1510]
MSM(3)-AR(4)	0.5705	12.0822*	19.6359*
	[0.8489]	[0.0005]	[0.0002]
MSMH(3)-AR(4)	0.0019	1.7223	5.2046
	[0.9652]	[0.1894]	[0.1574]

p-values are within brackets.
* denotes significance at the 5% level.

According to Table 1, the autoregressive lags for the MSI-type, MSM-type and MSMH-type models are four, while that for the MSIH-type model is at unity.

Before presenting the estimated results, we verify the C-K test results for the three asymmetries, as shown in Table 2. Worth noting is that if the non-deepness hypothesis is rejected by Clements and Krolzig's parametric tests, then we take this as strong evidence in favor of deepness based on Psaradakis and Sola (2003) and Clements and Krolzig's (2003) simulation results.[9] From the first column of Table 2, it is certain that the null hypothesis of non-deepness must not be rejected for any of the types of the Markov Switching Model.

The second column of Table 2 presents the C-K tests results for the null hypothesis of non-steepness for the four Markov Switching autoregressive models. The C-K test results for the MSI, MSIH and MSM models, but not the MSMH model, reject the null hypothesis of non-steepness, implying steep asymmetry is a characteristic of Taiwan's output growth rate. As pointed out by Verbrugge (1997), "the detection of steepness

[9] Psaradakis and Sola (2003) have pointed out: "...when the cyclical component of a time series is extracted by means of the HP procedures, much information about asymmetry in the true cyclical component is lost, resulting in tests having little power to detect deviations from symmetry. This implies that it is particularly important not to uncritically interpret failure to detect asymmetries in detrended time series as evidence in favor of symmetric cyclical behavior. Conversely, whenever asymmetry of the cycle is established using the familiar detrending methods, this can be taken as strong evidence in favor of asymmetry." The Monte Carlo results of Clements and Krolzig (2003) have also shown that "The parametric tests (a) behave as expected for correctly specified MS models, (b) are robust against skewness due to heteroscedasticity, and (c) have been found to be reliable tests for business cycle asymmetries even if the underlying DGP is different from the empirical model."

should lead the researcher to search among specifications that can capture that form of asymmetry, such as the Threshold Autoregressiive (TAR), the Self-Exciting Threshold Autoregressive (SETAR), or the Smooth Threshold Autoregressive (STAR) models." This evidence for steepness strongly suggests that non-linear models are preferable to linear models in describing Taiwan's business cycles.

As for the asymmetry of sharpness, it is of particular interest to note the third column of Table 2. We cannot arrive at a consistent conclusion concerning either of the four models, but a pattern nevertheless occurs. If conditional variance is not regime-dependent, then non-sharpness is rejected. Conversely, if conditional variance is regime-dependent, then we accept the non-sharpness hypothesis. Simply put, the conclusion we reach is that sharpness is model-dependent for the growth rates of GDP.

The test results make it difficult to draw a conclusion *vis-à-vis* sharp asymmetry in Taiwan's business conditions. For comparison purposes, we list the estimated results for the four Markov Switching autoregressive models in Table 3.[10] The corresponding posterior probabilities, including those of the filtered and smoothed probabilities, are plotted in Figures 2 and 3, respectively.

It is important to remember that in a two-regime Markov Switching Model, non-sharpness implies that $p_{12} = p_{21}$, and in a three-regime model, it required that $p_{12} = p_{32}$, $p_{13} = p_{31}$ and $p_{21} = p_{23}$. Observe the transition probability estimates, i.e., p_{ij}, $\forall\, i, j = 1, 2, 3$, for the MSI(3)-AR(4) and MSM(3)-AR(4) models. They are quite similar in both models. The duration for staying in the low-growth regime (regime 1) is very persistent because p_{11} is over 0.96 for both models, but the duration for staying in the normal-growth (regime 2) and high-growth (regime 3) regimes is quite short.[11] Moreover, the parameter estimates for p_{13} and p_{31} in both models are near zero, implying that a high-growth regime is never immediately followed and/or directly preceded by a low-growth regime, and vice versa.

Take the MSM(3)-AR(4) model as an example; this is also the model estimated by Huang (1999), with the posterior probabilities showing that Taiwan's economy was

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[10] All computations, including those from the asymmetric tests, are performed by the MSVAR module of the Ox software developed by Krolzig. It is both fast and robust in estimating the Markov Switching model. Although the MSVAR module does not provide estimates of the standard error for the transition probabilities, we can still test its significance (from zero) by its logits formation $\pi_{ij} = \log(p_{ij}/(1 - p_{ij}))$. See Clements and Krolzig (2003) for details. We double check the results by estimating the GAUSS code and find that they are quite similar. For consistence, we only present the results from the MSVAR module.

[11] The duration for staying in a particular regime is calculated by $(1 - p_{ii})^{-1}$, $\forall\, i = 1, 2, 3$.

Table 3 Estimated Results of the Three-Regime MS Models

Parameters	MSI(3)-AR(4)	MSIH(3)-AR(1)	MSM(3)-AR(4)	MSMH(3)-AR(4)
μ_1	−2.5506*	−1.7190*	6.2482*	6.2846*
μ_2	1.4944*	2.2005*	8.7283*	7.4167*
μ_3	5.4438*	4.0356*	11.5496*	9.8572*
α_1	0.8109*	0.6295*	0.7461*	0.7876*
α_2	0.0909		0.2473*	0.0570
α_3	−0.0123		−0.0874	0.0658
α_4	−0.2560*		−0.3363*	−0.3247
σ_1	1.2501*	0.8446*	1.1645*	0.6849*
σ_2		0.9407*		1.3854*
σ_3		2.0905*		2.3474*
p_{11}	0.9600*	0.7468*	0.9711*	0.9458*
p_{12}	0.0319*	$5.1e-7$	0.1119*	0.0427*
p_{13}	$1.1e-6$	0.0140	$3.8e-13$	$5.4e-12$
p_{21}	$2.1e-10$	0.0023	0.0288*	0.0542*
p_{22}	0.4450*	0.9730*	0.3475*	0.9572*
p_{23}	0.4900*	0.0348*	0.4021*	0.0153*
p_{31}	$6.9e-8$	0.2508*	$1.5e-11$	$5.2e-11$
p_{32}	0.5231*	0.0270*	0.5406*	$7.2e-8$
p_{33}	0.5100*	0.9512*	0.5979*	0.9846*
log-L	−287.3809	−293.3820	−291.7585	−284.3678

* denotes the rejection of the null hypothesis that the parameter equals zero at the 5% level.

in a low growth regime between 1980–1985 and the post-1990 periods. With regards to the pre-1980 period, Taiwan's economy oscillated between the normal-growth and high-growth regimes, as shown in the panel on the left of Figure 3. From the MSM(3)-AR(4) model, the estimated growth rates for the three regime are 6.25%, 8.13% and 11.55%, respectively, results which are quite similar to those of Huang (1999) who derived 5.78%, 9.5% and 12.15% for the three regimes from 1961:Q1 to 1996:Q4.

A three-state model is required to characterize a business cycle with contractions (low-growth regime), normal growth (normal-growth regime) and rapid growth (high-growth regime). One feature of the business cycle, as described by Friedman (1969, 1993), is referred to as "peak-reversion" or "the plucking model". We evaluate this hypothesis by testing the following restrictions: $p_{13} > p_{12}$; $p_{21} > p_{23}$; and $p_{32} > p_{31}$. For all four of the Markov Switching Models, this hypothesis is rejected.

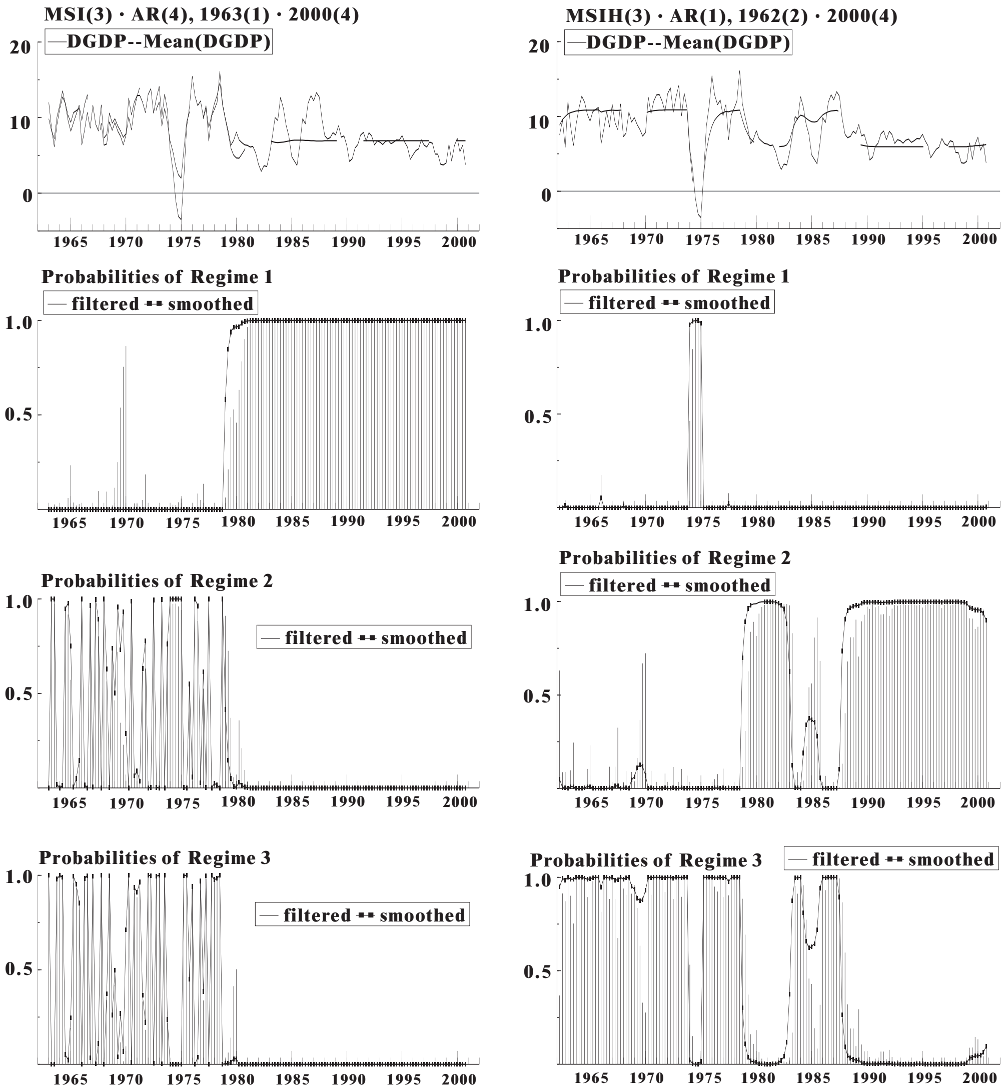

Figure 2 Posterior Probabilities of the MSI(3)-AR(4) (Panel on the Left) and MSIH(3)-AR(1) (Panel on the Right) Models, Respectively

Our test results for *non-deepness* provide further support for the previous empirical research of Huang (1999) and Chen (2002), who report that peak-reversion is not an acceptable interpretation of Taiwan's business cycles.

As far as the MSIH and MSMH models go, they display different patterns, with one of the most significant differences between the two models being the parameter

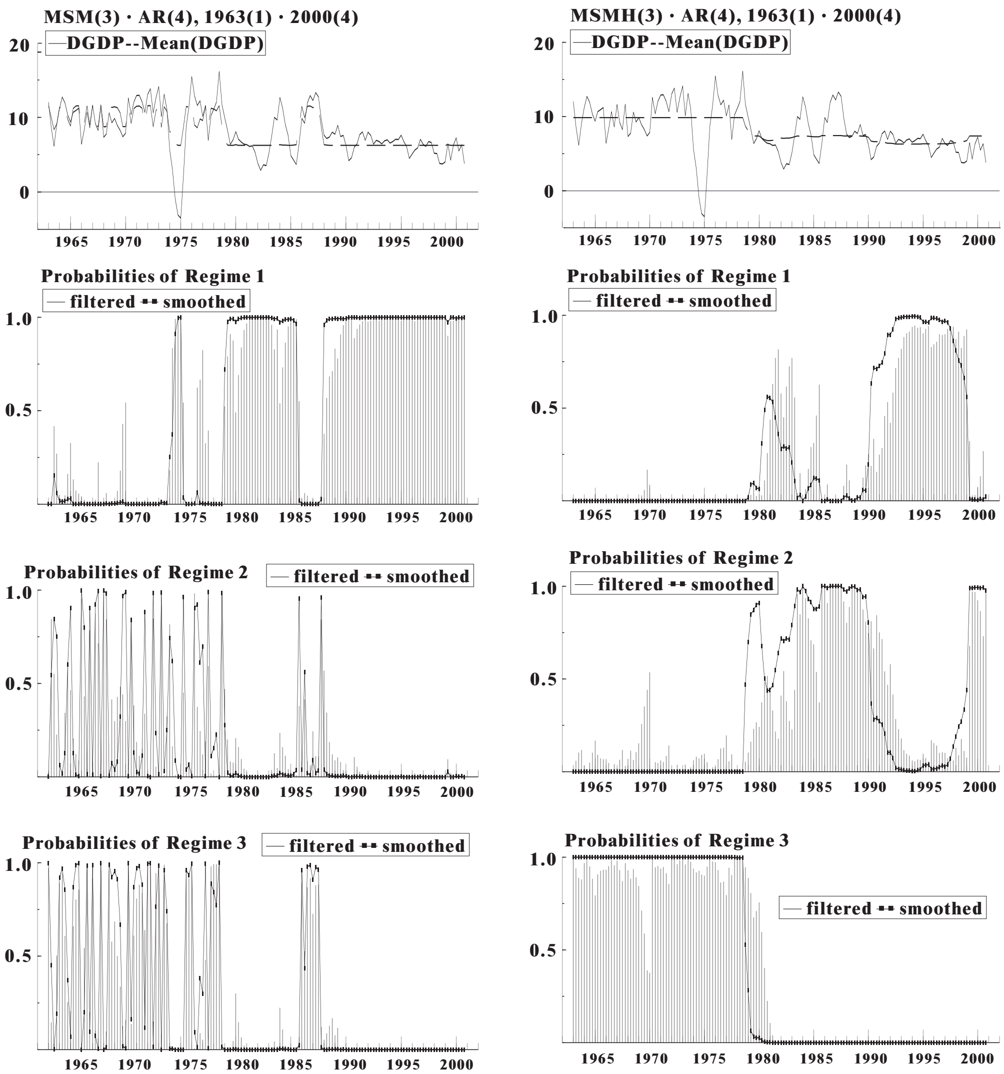

Figure 3 Posterior Probabilities of the MSM(3)-AR(4) (Panel on the Left) and MSMH(3)-AR(4) (Panel of the Right) Models, Respectively

estimate of p_{11}. For the MSIH model, it is 0.75, whereas for the MSMH model, it is 0.95. This difference in p_{11} contributes to the divergent pattern in the posterior probabilities of the two models, particularly in the low-growth regimes. For the MSIH model, the low-growth regime is only in 1974, while for the MSMH model, it is in the 1990 to 1999 period.

When we compare all models in terms of the SBC results in Table 1, then we come to the conclusion that the final model to be chosen should be MSIH(3)-AR(1). From our "subjective perspective", on the basis of the posterior probabilities in the panel on the right of Figure 2, we think that this model's prediction is more consistent with the history of Taiwan's economy than are the other models. For example, before 2000, Taiwan experienced one period of negative growth, i.e., in 1974, as evidenced by MSIH's low-growth regime probability. Moreover, the average growth rates in the post-1990 (regime 2) are lower than those in the pre-1990 period (regime 3). From the "objective viewpoint", we summarize some diagnostic checking by plotting the predicted and standardized errors in Figure 4. The statistical properties of the standardized errors and predicted errors are shown in the upper and lower panels of Figure 5. As shown in Figure 4, the predicted errors indicate that the volatility of the process shrinks after 1990. From the graphs in Figure 5, it is clear that no strong autocorrelation remains in the errors and that the normality hypothesis is accepted for the standardized and predicted errors. We conclude that the MSIH(3)-AR(1) model is a valid, albeit *approximate*, statistical representation of Taiwan's business cycle.

One potential problem of the MSIH(3)-AR(1) model, however, is that the recession dates that it identifies are totally different from the chronology reported by the Council for Economic Planning and Development (hereafter CEPD), but they are consistent with the recession dates determined by the Economic Cycle Research Institute (ECRI). According to the ECRI's report, before 2000, Taiwan experienced only one business cycle between December 1973 and January 1975. This could mean that, in concept, the turning points of the peaks and troughs reported by the CEPD are for the *growth cycle*, and not for the business cycle. Another possible explanation is that the volatility of Taiwan's output growth rates changes. Evidence of this *conjecture* can be found in the predicted errors in Figure 4 where we note that the volatility of the process decreases after 1990. One possible solution for this problem is provided by McConnell and Perez-Quiros (2000) who consider a two-state Markov Switching Model which allows that the conditional mean must be dependent on two unobserved state variables, one for average growth rate and the other for business variation.[12]

[12] McConnell and Perez-Quiros (2000) showed that the volatility of U.S. output decreased in 1984Q1.

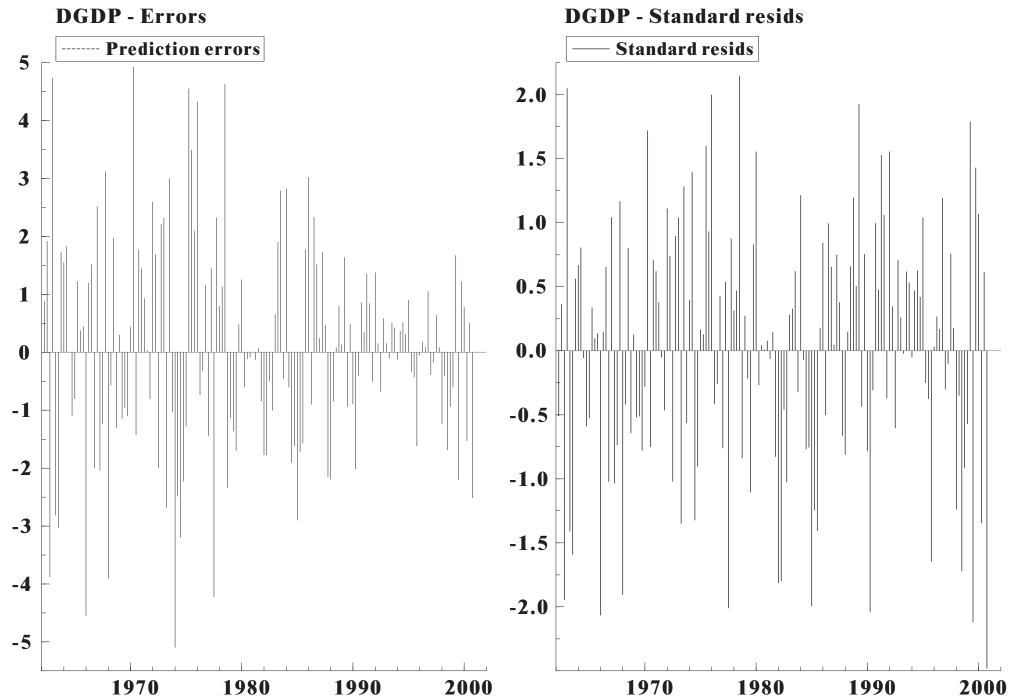

Figure 4 Predicted and Standardized Errors of the MSIH(3)-AR(1) Model

5. CONCLUDING REMARKS

In this paper, we examine the asymmetric features of Taiwan's business fluctuations. In particular, we check deepness, steepness and sharpness asymmetries for the real growth rate of the gross domestic product in Taiwan. We find that the non-deepness property is overwhelmingly acceptable in Taiwan, but non-steepness is strongly rejected by the Clements and Krolzig parametric tests. The evidence for steepness suggests that in characterizing Taiwan's business cycles, non-linear models are preferable to linear ones. The conclusion we arrive at for the property of sharpness is inconclusive and is model-dependent. We also check the asymmetric properties for fourteen key macroeconomic time series.

Aside from those of the tests used in this paper, researchers report many asymmetric test statistics in the literature, for example, the time irreversibility (TR) test of Ramsey and Rothman (1996) and Chen, Chou, and Kuan (2000) and the asymmetric

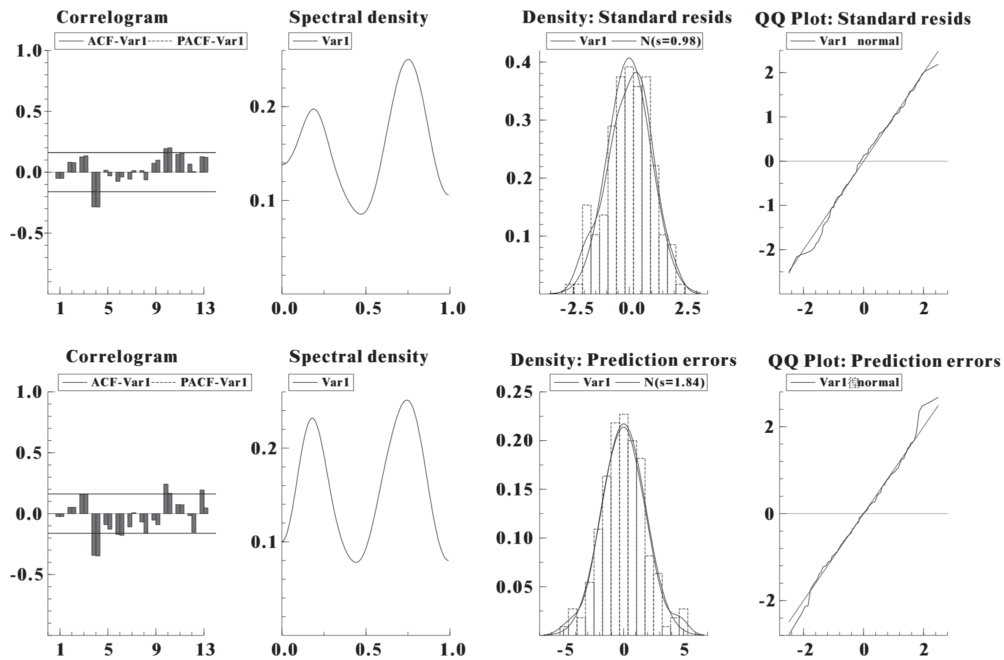

Figure 5 Statistical Properties of the Standardized Errors (Top Panel) and Predicted Errors (Bottom Panel) in the MSIH(3)-AR(1) Model

test of Bai and Ng (2001). Further avenues of research might combine all of these test statistics together in an attempt to check the asymmetry of a time series.

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臺灣景氣波動不對稱性特色之檢定

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摘　要

本文採用 Clements and Krolzig 的檢定方法探討臺灣景氣循環不對稱性的特色, 包括以下三種: 深度, 斜度及尖度不對稱性。我們以季節調整後的實質 GDP 成長率進行實證分析, 實證結果發現臺灣的景氣循環並不具備深度的不對稱性特色, 但是支持斜度的不對稱性特色, 顯示以非線性模型比線性模型更適合於描述臺灣景氣循環特色。至於尖度不對稱性則是無法得到一致的結論, 檢定結果會因模型的設定不同而改變, 顯示有模型相依的結果。