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The performance of the Markov-switching model on business cycle identification revisited

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This study examines the performance of Markov-switching model on business cycle by applying the model to various economies. Specifically, three comparison groups are used: (1) the USA and Japan serving as the representatives for the industrialized economies (or IEs hereafter); (2) Taiwan and South Korea serving as the representatives for newly industrialized economies (or NIEs hereafter); and (3) Malaysia and Indonesia serving as the representatives for the developing economies (or DEs hereafter). The empirical results are consistent with the following notions. First, the Markov-switching model serves well to depict the business cycles for IEs and DEs. Nevertheless, the model is ineffective for the two NIEs, which underwent structural economic shifts to slower growth during our sample period of 1970–1998. Second, the two-period Markov-switching by dividing the sample periods into two sub-periods thus more effectively measures the two NIEs' business cycles.

1. Introduction

This study examines the performance of the Markov-switching model on business cycle identification by applying the model to various economies. Specifically, three alternative groups are used: (1) the USA and Japan serving as the representatives for the industrialized economies (or IEs hereafter); (2) Taiwan and South Korea serving as the representatives for the newly industrialized economies (or NIEs hereafter);

and (3) Malaysia and Indonesia serving as the representatives for the developing economies (or DEs hereafter).¹

Since Hamilton (1989), the MS models have become increasingly popular in measuring macroeconomic fluctuations. Many prior studies have applied the technique or continuously established some more advanced versions. Kim's (1994) a general state-space specification and Filardo's (1994) framework with a time-varying transition probability setting serve as

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¹The IEs' per capita GDP are significantly greater than the NIEs', which in turn are significantly greater than the DEs'. For instance, the 1999's per capita GDPs of the US and Japan (the two IEs) are 34 047 and 34 360 dollars, respectively. The 1999's per capita GDPs of South Korea and Taiwan (the two NIEs) are 8684 and 14 024 dollars, respectively. The corresponding measures of Malaysia and Indonesia (the two DEs) are 3242 and 1055 dollars, respectively.

two of the representatives. Besides, Layton and Smith (2000) proposed a three phrase version of the MS model in contrast with Hamilton's (1989) two phase version for the US business cycle. Layton and Masaki (2001) followed Filardo (1994) to design the MS model with a signalling system for the business cycle turning point and applied the specification to analyse the business cycle pattern of the USA, Japan and Australia. Stanca (1999) adopted the threshold autoregressive and MS models with a two-regime setting to analyse several Italian macro-economic and demonstrated the regime-switching pattern could serve as one of explanations to the observations of nonlinearity behaviours of macro-economic variables. Layton (1997) applied the quasi-Bayesian MS model to both the coincident and leading indexes of Australian economic activity and demonstrated the resultant regime probability from the application to leading index could serve a reliable signalling system for Australian business cycle phase changes.

Among the prior studies, however, Goodwin (1998) shows that the MS models fail to capture some non-linearity properties for some economies, especially for Italy, for which the conventional MS models identify several outliers as separate states and thus fail to depict the patterns of the business cycles.²

Moreover, Krolzig (2001) showed that the two-regime MS models fail to depict the business cycles for the USA and Japan because of the two countries' substantial change in the stochastic process of economic growth. Specifically, the USA experienced long expansions in 1990s, whereas in Japan there were both long episodes of rapid economic expansion until 1970 and a long recession in the 1990s. Krolzig (2001) argued that his results support the notion of structural change in the two economies' business cycles and that three- as opposed to two-regime MS models should be adopted.

This study's concern is that more (less) developed nations appear to have lower (higher) economic growth. Thus the conventional two-regime MS models may fail to depict the regime switches and to identify the recession and the boom stages for the economies that experience non-recurring shifts to a higher- or lower-growth stage. Nevertheless, few, if any, prior study aims at exploring the effectiveness of the conventional MS model in the

newly industrialized economies, for which the ineffectiveness of the conventional MS model may be more pronounced.

This study establishes empirical evidence for the presence of another limitation of the conventional MS models and introduces a remedy measure.³ It demonstrates that the MS models are also ineffective for data sets subject to non-recurring structural shifts. For studies with test periods covering both higher-growth (the earlier) and the lower-growth (the later) stages of the NIEs, depicting the patterns of the business cycles may be impossible even if one increases the number of regimes.

Empirical evidence supports the notion of NIEs' non-recurring shifts to lower economic growth. Accompanying substantial changes in industry and international trades for South Korea and Taiwan since 1990, the IP growth rates of the two NIEs in recent years differ substantially from the measures in the 1980s. The average annual IP growth rates for South Korea and Taiwan are 15.8% and 6.8% during 1970–1989, respectively, while they were 6.6% and 4.4% during 1990–1998, respectively. Although the latter (former) measure is significantly less (greater), one should not conclude the recession remains throughout the latter stage. Specifically, the core of the economies is the less (more) capital intensive, more (less) labour intensive and less (more) technology intensive sectors before (after) 1990. Moreover, according to the histories of developing countries, the pre-1990 high growth rate of South Korea and Taiwan may not recur, because the industrial and exportation structures shifted substantially. Accordingly, studies with the sample period over the last two or three decades may be unable to identify an economic boom or contraction for the NIEs via examining the mean growth rates. As to standard deviations, the pre-1990 measures of IPs for South Korea and Taiwan were 10.2% and 13.1%, respectively. In contrast, the post-1990 standard deviations for the two NIEs were 7.2% and 4.0%, respectively. The variance of the annual IP growth rates for the NIEs also decreased substantially since 1990.

The features of this paper are as follows. First, with the prior that the NIEs may have more pronounced structural economic shifts, six countries are partitioned with different development phases, industrialized (USA and Japan), newly industrialized (Taiwan and South Korea) and developing (Malaysia and

²Goodwin (1998) provides evidence supporting the notion that the MS models incorporating a quasi-Bayesian prior effectively depict the business cycles for UK, Japan and France, but not for Italy. Goodwin (1998), nevertheless, does not provide any explanations or remedies as to the ineffectiveness of the MS models for Italy.

³Prior studies on the ineffectiveness of the MS models do not specify the particular types of the economies that may encounter such problems. Nor do they provide any explanations or remedies to mitigate the ineffectiveness problems.

Indonesia) economies, comparing the business cycle patterns among the three groups. Second, it documents the ineffectiveness of the conventional MS models for the NIEs and establishes more descriptive two-period MS models to eliminate the ineffectiveness problem.

The next section presents the performance of business cycle identification of the conventional MS model on various economies. Section III presents the specification and institution of the two-period MS model created by this paper and the performance of the model on the two NIEs. Finally, Section IV concludes the study.

II. Is the MS Model Suitable for all Economies?

The MS setting

Denoting y_t as the annual growth rate of IPs, the MS model in this study has the following settings:

$$y_t = \alpha_{s_t} + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \dots + \phi_q y_{t-q} + e_t$$

where $e_t \sim \text{i.i.d. } N(0, \sigma^2)$, and s_t is an unobservable state variable with possible outcomes of $1, 2, \dots, K$. Further assume that s_t follows a one-order Markov-chain process. Take a two-regime MS setting as an example. It incorporates unobservable regime variable $s_t = 1, 2$. Specifically, y_t is generated via two normal distributions with differential means and unit standard deviation σ . If $s_t = 1$, then the mean of y_t is $u_1 = \alpha_1 / (1 - \Phi_1 - \Phi_2 - \dots - \Phi_q)$, and if $s_t = 2$, then the mean of y_t is $u_2 = \alpha_2 / (1 - \Phi_1 - \Phi_2 - \dots - \Phi_q)$. In a $\alpha_1 < \alpha_2$ setting, one can set $s_t = 1$ ($s_t = 2$) for the low (high) growth regime. In short, the two-regime setting incorporates both high- and low-intercept measures and a unique measure for standard deviation.

The two-regime Markov transition probabilities can be expressed as follows:

$$\begin{aligned} p(s_t = 1 | s_{t-1} = 1) &= p_{11}, & p(s_t = 2 | s_{t-1} = 1) &= p_{12} \\ p(s_t = 2 | s_{t-1} = 2) &= p_{22}, & p(s_t = 1 | s_{t-1} = 2) &= p_{21} \end{aligned}$$

where $p_{11} + p_{12} = p_{21} + p_{22} = 1$. The stochastic process for s_t is strictly stationary if both p_{11} and p_{22} are less than unity and does not simultaneously take on the

value of zero. When $p_{11} = 1$, once the process enters state 1, then it would never return to state 2.⁴

The empirical data are the annual growth rate.

$$y_t = 100 \cdot (\log Y_t - \log Y_{t-12})$$

where $\log Y_t$ denotes the natural logarithm of monthly IP. Appreciating the annual growth rate setting could eliminate most short-run dynamic processes. In a simple setting, one lets the lag order of y_t be the one to control the residual dynamic process in the estimating periods.⁵

Although the regime variable s_t in the MS model is unobservable, one still can use the data to estimate the specific regime probabilities in time t . When the information set for estimation includes signals dated up to time t , the regime probability is a $p(s_t | y_t, y_{t-1}, \dots)$, or *filtering probability*. On the other hand, one could also use the overall sample period information set to estimate the state at time t : $p(s_t | y_T, y_{T-1}, \dots)$, or *smoothing probability*. In contrast, a *predicting probability* denotes the regime probability for an ex ante estimation, with the information set including signals dated up to the period $t-1$: $p(s_t | y_{t-1}, y_{t-2}, \dots)$.⁶ Based on the classification of Hamilton (1989), wherein an observation belongs to state i if the smoothing probabilities $p(s_t | y_T, y_{T-1}, \dots)$ are greater than 0.5, the annual growth data y_t is divided into two regimes, the high-growth rate regime and low-growth rate regime. The most pronounced difference between the MS and the alternative structural change specifications is that the former can estimate the specific regime probability for any time t by the data itself, and automatically identify and predict the high and low-growth state at time t .

The performance of business cycle identification of the MS model on various economies

OPTIMUM is used, a package program from GAUSS, and the built-in BFGS algebra to get the estimators that maximize the value of log-likelihood function.⁷ In estimation of the MS model, 50 sets of initial values are randomly generated. The ML function value is then derived for each of the 50 sets of the initial value respectively. The mapped converg-

⁴In such a case, state 1 is an absorbing state and the Markov chain is reducible.

⁵In a sensitivity test, we use higher order settings, which yield insignificantly improvements over the lower order settings. On the other hand, we think that the effectiveness of identifying business cycles does not significantly relate with the lag order numbers.

⁶ $p(s_t | y_{t+r}, y_{t+r-1}, \dots)$, if $r = 0$: filtering probabilities; $r < 0$: predicting probabilities; $r > 0$: smoothing probabilities.

⁷Boyden, Fletcher, Goldfarb, and Shanno (BFGS) algebra is effective in deriving the estimators to maximize the value of the likelihood functions for non-linear models. See Luenberger (1984).

Fig. 1. Annual growth rates of IPs and smoothing recession probabilities of MS model for two representative IEs

ing measure of the greatest ML function value then serves to estimate the parameter.

The database provided by IMF International Financial Statistics (IFS) Databank contains the monthly IPs for the USA, Japan, South Korea and Taiwan between January 1970 and December 1998, the monthly IPs for Malaysia between January 1972 and December 1998, as well as the monthly IPs for Indonesia between July 1972 and December 1998. Accordingly, the sample includes 328 observations for each of the IEs (the USA and Japan) and NIEs (South Korea and Taiwan). Furthermore, the sample includes 324 and 318 observations, for Malaysia and the Indonesia, respectively.⁸

Figures 1, 2 and 3 present the annual growth rates of IPs and the contraction regime's smoothing probabilities of the MS model for three economy groups: IEs, NIEs and DEs, respectively. The results support the notion that the MS model appears to be effective in depicting boom and contraction regimes of IEs and DEs. In contrast, the MS model fails to identify the post-1990 business cycles for the two NIEs. Specifically, the MS model would result in

a conclusion that the two NIEs have persistently been in a recession regime (a low-growth regime) since 1990.

Table 1 presents the estimates of the MS models for the IEs and DEs. It shows that the mean growth rate for the high-growth regime (hereafter u_2) of IEs is less than for DEs. Specifically, u_2 estimates of the USA and Japan are 8.353 and 5.191, respectively. The u_2 estimates of Indonesia and Malaysia are 19.334 and 37.257, respectively. Consistently, the mean growth rate for the low-growth regime (hereafter u_1) of the IEs is less than for the DEs. Specifically, u_1 estimates of the USA and Japan are -13.750 and -8.559, respectively. The u_1 estimates of Indonesia and Malaysia are -2.681, 1.572, respectively. This documents that the magnitude of both high and low-growth rate regime means are less (more) in the IEs (DEs).

The magnitude of the standard deviation (hereafter σ) is then examined, denoting the volatility of IP's annual growth rate. The σ of IEs is less than for the DEs. Specifically, σ estimates of the USA and Japan are 1.099 and 2.674, respectively, while

⁸IP is used as opposed to GDP in order to obtain a large enough sample of the post-1990 business cycles for the two NIEs. Specifically, IP (GDP) measures are reported monthly (quarterly). Because of the need to separate data into two periods to control the structural shifts of South Korea and Taiwan, it appears to be desirable not to over-parameterize the model. Furthermore, the production functions most typically incorporate labour as an input variable and can thus reflect the level of unemployment of an economy.

Fig. 2. Annual growth rates of IPs and smoothing recession probabilities of MS model for two representative NIEs

σ estimates of Indonesia and Malaysia are 6.465 and 6.189, respectively. This indicates that the volatility of IP growth is less (more) in IEs (DEs).

III. Eliminating the Ineffectiveness of the MS Model in Depicting the Business Cycles of NIEs

The potential explanation for the ineffectiveness of MS models is that the MS models fail to control the structural shifts. So, the following two-period MS models are established to examine the IPs of the two NIEs.

The two-period MS setting

$$\begin{aligned}
 y_t &= \alpha_{s_t}^B + \phi_1^B y_{t-1} + \phi_2^B y_{t-2} + \cdots + \phi_q^B y_{t-q} \\
 &\quad + e_t^B, \quad \text{for } 0 < t \leq tw \\
 y_t &= \alpha_{s_t}^A + \phi_1^A y_{t-1} + \phi_2^A y_{t-2} + \cdots + \phi_q^A y_{t-q} \\
 &\quad + e_t^A, \quad \text{for } tw < t \leq T
 \end{aligned}$$

where tw denotes the time when structural shift is happening, and $e_t^B \sim \text{i.i.d. } N[0, (\sigma^B)^2]$ as well as $e_t^A \sim \text{i.i.d. } N[0, (\sigma^A)^2]$. The two-period MS models incorporate two sets of high- and low- regime means as well as variance to depict the business cycle of the different developing stages in the NIEs. Specifically, the two-period MS models incorporate the conventional Markov Switch and single- structural-shift specifications. The single shift models depict the economic turning process, whereas the MS models depict the movements along the business cycles.

To pinpoint the exact time for structural change, a reasonable prior is the time point that the single MS models cannot identify the business cycle. In other words, the single MS models cannot identify if the business cycle should be relative to structural shifts. The empirical findings indicate that the single MS model could not identify the business cycle of the two NIEs beginning in March 1988 and in August 1987, respectively.⁹ Accordingly, in the two-period MS models the two points are adopted in time as the cut-offs for South Korea and Taiwan's annual growth of IP.¹⁰

⁹The months surrounding the time when the MS models fail to depict the business cycles of the two NIEs to partition the South Korea and Taiwan IPs data have also been adopted. None of the alternatives appears to be more effective in depicting the business cycles.

¹⁰The potential reasons that the two NIEs' economic growth and volatility dropped substantially include exchange rate factors, the change of product modes, the more mellow industry's incorporating, the more stable price for input factors and output goods and so on.

Fig. 3. Annual growth rates of IPs and smoothing recession probabilities of MS model for two representative DEs

Table 1. Estimates of the MS model for industrialized and developing economies

	p_{22}	p_{11}	α_1	α_2	Φ_1	σ	u_1	u_2
<i>Panel A. Industrialized Economies (IEs)</i>								
USA	0.966 (0.016)	0.901 (0.043)	-0.935 (0.196)	0.568 (0.104)	0.932 (0.015)	1.099 (0.045)	-13.750	8.353
Japan	0.986 (0.010)	0.937 (0.054)	-1.301 (0.546)	0.789 (0.447)	0.848 (0.052)	2.674 (0.113)	-8.559	5.191
<i>Panel B. Developing Economies (DEs)</i>								
Indonesia	0.903 (0.052)	0.970 (0.014)	-1.099 (0.552)	7.927 (1.340)	0.590 (0.055)	6.465 (0.291)	-2.681 1.572	19.3 4
Malaysia	0.973 (0.017)	0.942 (0.035)	0.239 (1.642)	5.663 (0.986)	0.848 (0.052)	6.189 (0.264)		37.25 7

Note: The estimates for the standard errors are shown in parentheses.

Two-period and two-regime versus four-regime MS models

This study's two-period MS models use u_2^B and u_1^B for high and low growth means in the first developing stage, and use u_2^A and u_1^A when middle-developed countries come to intermediate growth phase. The two-period MS setting is seemingly identical to the four-regime MS models in its incorporating four mean parameters. But the two settings differ in two ways.

First, the four-regime MS models has four growth mean parameters including u_1 , u_2 , u_3 and u_4 , can depict the more complex regime switching type, but cannot describe the structural economic shifts in the NIEs. Moreover, because of different technology levels in the NIEs' various developed stages, it may be ineffective if one only uses unique mean parameter values to document the more booming or the more contracting economic regimes. As opposed to the two-period MS models in this study, the two sets of low and high growth regime means for various

Fig. 4. Annual growth rates of IPs and smoothing recession probabilities of two-period MS model for two representative NIEs

developed stages can depict the structural shifts of NIEs.

Moreover, to control the regime switching process for four regime MS models, we have to adopt the 4×4 transition probability matrix, and estimate 12 unknown probability parameters.

$$P = \begin{bmatrix} p_{11} & p_{21} & p_{31} & p_{41} \\ p_{12} & p_{22} & p_{32} & p_{42} \\ p_{13} & p_{23} & p_{33} & p_{43} \\ p_{14} & p_{24} & p_{34} & p_{44} \end{bmatrix}$$

In contrast with the two-period MS models in this paper, due to two regimes setting, only need 2×2 transition probability matrix, and two unknown parameters. The reasons are that there exist some prior constraints in two-period MS models. Specifically, the two prior constraints are (1) p_{11} , p_{12} , p_{21} , p_{22} , p_{33} , p_{34} , p_{43} and p_{44} are non-zero, and (2) p_{13} , p_{14} , p_{23} , p_{24} , p_{31} , p_{32} , p_{41} and p_{42} are all zero. To describe the structural economic shifts for NIEs, the prior constraints are reasonable. To sum up, the two seemingly identical models differ in two ways. First, the two-period MS (four regime MS) models need less (more) parameter. Second, the two-period MS (four-regime MS) models can (cannot) depict the structural economic shifts in NIEs' growth process.

Empirical results of the two-period MS model on two NIEs

The smoothing probabilities of contraction regime of South Korea and Taiwan estimated by the two-period MS model are presented in Fig. 4. The results show that the two-period MS models can well depict the business cycles of the two NIEs for both pre- and post-1990 periods.

Table 2 presents the two-period MS model estimates for both NIEs. Note that the high-growth regime means in the low-growth stage (hereafter u_2^A) of South Korea and Taiwan are 8.937 and 6.356, respectively. The corresponding measures in the earlier high-growth stage (hereafter u_2^B), or 23.931 and 19.330, are significantly less. Moreover, the low-growth regime means in the low-growth stage (or u_1^A hereafter) for South Korea and Taiwan are -3.164 and 0.944 , respectively. In contrast, the corresponding measures in the earlier high-growth stage (or u_1^B hereafter) are 8.017 and 2.436, respectively. Evidently, both high- and low-regime means of the NIEs decreased in the 1990s. Table 2 also shows that, consistent with the results of Table 1, the pattern of IP growths for the NIEs is less (more) volatile in the better- (less-) developed stage. The standard error in the earlier

Table 2. Two-period MS model estimates for the newly industrialized economies

<i>Panel A. High-growth stage</i>								
Parameters	p_{22}^B	p_{11}^B	α_1^B	α_2^B	Φ_1^B	σ^B	u_1^B	u_2^B
Taiwan	0.972 (0.017)	0.956 (0.024)	0.804 (0.697)	6.379 (1.261)	0.670 (0.061)	5.135 (0.267)	2.436	19.33 0
South Korea	0.968 (0.016)	0.955 (0.021)				6.220 (0.307)	8.017 (0.694)	23.93 1 (0.627)
<i>Panel B. Medium-growth stage</i>								
Parameters	p_{22}^A	p_{11}^A	α_1^A	α_2^A	Φ_1^A	σ^A	u_1^A	u_2^A
Taiwan	0.946 (0.041)	0.893 (0.061)	0.551 (0.787)	3.712 (0.909)	0.416 (0.098)	2.787 (0.197)	0.944	6.356
South Korea	0.982 (0.013)	0.932 (0.057)				5.809 (0.323)	-3.614 (1.264)	8.937 (0.527)

Notes:

1. $(u_i^B, \sigma^B, p_{ij}^B)$ and $(u_i^A, \sigma^A, p_{ij}^A)$ denote (regime i mean, standard error, transition probabilities from regime i to regime j), in the high- and low-growth stage, respectively.

2. In estimating the annual growth rate of IP for South Korea, the AR coefficient is dropped. Even though one does not incorporate AR setting, one can still identify South Korea's business cycle, because the problems in identifying the NIEs' business cycle are not AR setting, are economic structural shifts.

high-growth stage (hereafter σ^B) for South Korea and Taiwan are 6.220 and 5.135, respectively. The corresponding estimates for the later low-growth stage, in contrast, are 5.809 and 2.787 (hereafter σ^A).

IV. Conclusion

The empirical findings support the following notions. First, the MS model could capture the business cycle of the IEs (including the USA and Japan) and the DEs (including Indonesia and Malaysia), but not for the NIEs (including South Korea and Taiwan). Specifically, MS models failed to depict the post-1990 period business cycles of the two NIEs, which may have experienced industry structural shifts. Second, the data is partitioned into two stages including high and medium-growth stages, adopting the two-period MS models to estimate each other can well identify the post-1990 business cycles of the two countries. Third, two-period MS models are used to estimate the annual growth of IPs for South Korea and Taiwan. Both high and low-growth regime means as well as the standard deviation of the two NIEs are less (greater) in the second (first) periods. This result is consistent with the notion of structural shifts to a more industrialized stage in 1990s for the two NIEs.

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