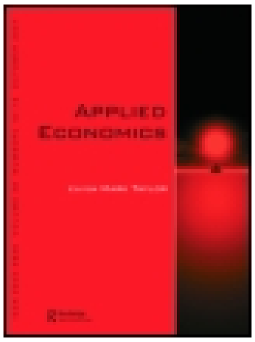

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A new turning point signalling system using the Markov switching model with application to Japan, the USA and Australia

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A new business cycle turning point signalling system is proposed and examined by using Japanese, US and Australian composite indexes of economic activity. Time varying transition probabilities in a Markov regime-switching model are used as the basis of the signalling system. The performance of the system is satisfactory, though its reliability varies between peaks and troughs and across countries. Based on data up until May 1998, the system suggests the absence of turning points in any of the three countries in 1998.

I. INTRODUCTION

One of the most important issues for macroeconomic policy makers when making decisions about stabilization policies is to predict the most likely time of the next business cycle turning point. In particular, in Japan at the time of writing, the government is endeavouring to devise and implement policies to assist the economy out of its present deep recession. The timing of the Japanese economic recovery is of utmost interest to the Japanese government, other national governments, and international financial markets. Similarly in the USA, analysts are keenly interested in how long the present long expansion will continue.

The purpose of this paper is to propose a new empirical signalling system of turning points in the economy, to examine the validity of the system using Japanese, US and Australian coincident and leading indexes, and to provide information on the likelihood of imminent future turning points in the three countries. While some methods for predicting turning points have been proposed as described in the next section, the signalling system proposed here is based on the Markov regime-switching model originally developed by Hamilton (1989). This paper employs the two phase, time varying transition probability, regime-switching model developed by Diebold *et al.* (1994), Filardo (1994) and Durland and McCurdy (1994).[1] Suitable signalling rules for predicting turning points are developed by calculating time varying transition probabilities of contraction and expansion using leading indicators as explanatory variables.

In the leading indicator approach to business cycle analysis, developed originally by Burns and Mitchell (1946) at the National Bureau of Economic Research (NBER), instead of basing a business cycle chronology on a single series, analysts prefer to use a diffusion index (DI) or composite index (CI). Relatedly, recent developments have occurred in dating and predicting turning points using time series econometrics techniques to calculate probabilities of being in particular business cycle phases or the likelihood of future turning points. Wecker

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[1] For applications of the time varying transition probability model in the business cycle context, see Durland and McCurdy (1994), Layton (1998) for the USA, and Layton (1996) for Australia.

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(1979), Neftci (1982), Hamilton (1989)[2] and Stock and Watson (1991, 1993) are important relevant papers. This empirical work combines the leading indicator and regime-switching modelling approaches in that it applies a variable transition probability, regime-switching model using cyclical leading and coincident indicators. The transition probability calculated in the model is used to determine empirical rules for predicting turning points.

The next section presents some existing rules for predicting turning points using the leading indicator approach. Section III outlines the regime-switching model and proposes the turning point signalling system. Section IV provides the empirical results for the USA, Japan and Australia. Applying the empirical rules of Section III, it is shown that historical turning points would have been quite well predicted using the signalling system in the three countries. This paper also comments upon the possibility of turning points occurring in Japan (trough), the USA and Australia (peaks) over the horizon immediately following the sample period available at the time of the analysis (endpoint – May 1998). Section V contains some concluding remarks.

II. SOME RULES FOR PREDICTING TURNING POINTS

Indicator approach

In the indicator approach, leading and coincident indexes are important inputs into the dating and prediction of turning points. When a DI is used, the point at which the coincident DI crosses the 50% line from above (below) determines a peak (trough). The point at which the leading DI crosses the 50% line determines the number of months lead in respect of the turning point in question. Cumulative DI is also often used for dating and predicting turning points.[3] The number of months between turning points in the leading indicators and coincident indicators at business cycle turning points are analysed in so-called lead-lag tables. Average or median leads and their standard deviation are utilized for assessing the reliability and stability of the leading indicators. As a DI often displays considerable irregularities in monthly movements, a three month rule is often adopted for dating and predicting turning points; i.e. a judgement that a trough (peak) will occur is made only if the DI is below (above) the 50% line for three successive months after crossing the line.

For CIs, turning points in the series itself represent turning points in the business cycle. Using a coincident CI along with a leading CI in combination with a three month type of rule allows turning points to be dated and predicted. See Zarnowitz and Boschan (1975a, b).

Another signalling system for predicting turning points using CIs was proposed by Zarnowitz and Moore (1982). They explored sequential signals empirically by using both a leading index (L) and a coincident index (C). L and C are appropriately smoothed growth rates of leading and coincident CIs. Their signals for peaks (troughs) consist of three stages as follows:

1. $L < 3.3$ and $C > 0$ ($L > 0$ and $C < 0$);
2. $L < 0$ and $C < 3.3$ ($L > 3.3$ and $C > 0$);
3. $L < 0$ and $C < 0$ ($L > 3.3$ and $C > 3.3$).

where 3.3% is the long term trend percentage growth rate inherent in the CIs.

In addition to the above rules they also used subjective judgement based on their assessment of actual CI growth rates. Another point to note is that they proposed three stages in signalling turning points. Occasionally, only the first and/or the second signals occurred, but the third did not; i.e. no turning point eventuated. Also the first signal sometimes had a long lead (particularly for peaks) to the turning point. The signals proposed here are similar to their approach though the growth rate of CI as the basis of the system is not used. Instead, time-varying transition probabilities arising from the regime-switching econometric model are used with only two stages of signals utilized.

A probabilistic approach to turning point prediction

The probabilistic approach evaluates the possibility of a turning point by computing, in some way, its probability of occurrence. In Wecker (1979), two binary variables representing peaks and troughs were defined as functions of some variable thought to be useful in predicting turning points. Based on these two binary variables, the variable w_t, 'time until the next turning point', was introduced and the empirical distribution of w_t calculated by simulation. In this method, the signal of the next turning point is the time, w_t, with the highest probability attached.

Neftci (1982) proposed sequential probability recursion methods for calculating the probability, π_t, of the occurrence of turning points. π_t is calculated recursively by the following formula:

$$\pi_{t+1} = \frac{[\pi_t + P(Z = t+1|Z > t)\{(1-\pi_t)p^1_{t+1}\}]}{[\pi_t + P(Z = t+1|Z > t)(1-\pi_t)p^1_{t+1} + (1-\pi_t)p^0_{t+1}\{1 - P(Z = t+1|Z > t)\}]},$$

[2] The Neftci (1982) approach can be regarded as a special case of Hamilton's model.

[3] When cumulative DI is used, its own turning point represents the turning point of the business cycle. Tahara (1983) also proposed that turning points of DI themselves could be utilized for predicting turning points because of their longer leads than the timing of crossing the 50% line.

where Z denotes the time of the next turning point, and p^0 and p^1 denote the conditional densities of the variable during normal and contractionary regimes, respectively. The turning point signal occurs when π_t exceeds some high probability, say 0.90 or 0.95. Niemira (1991) applied this method to leading indicators for the USA, the UK, Japan and West Germany, and using 95% as the threshold for predicting turning points, obtained useful results.

Hamilton's Markov, constant transition parameter, regime-switching model – as described in the next section – provides the probability that the economy is in one phase or another in any period.[4] Using these probabilities, Hamilton (1989) tried to establish a business cycle chronology for the USA using GDP growth rate. The rule he used was that: whenever the probability of contraction (expansion) was over (less than) 0.5, the economy was considered to have transitioned into contraction (expansion). Layton (1996) extended this basic approach to using a USA composite coincident index and the rule that: given the series was currently in an expansionary (contractionary) phase, a contractionary phase shift was identified as having occurred if a run of at least 'five' data point regime probabilities in a row exceeded (were less than) 0.5.[5] Layton (1997a) applied the same rule in dating and predicting Australian business cycles.[6]

II. A VARIABLE TRANSITION PROBABILITY, REGIME SWITCHING MODEL AND A DATING/PREDICTION RULE

Regime switching model

Hamilton (1989, 1990) has proposed the constant transition probability, Markov regime-switching model to allow for non-linear shifts in a time series from one phase into another. For each phase, the distribution of the variable under study is assumed to be normal with different means and variances, and the probability of switching from one phase into the other is characterized by a first order Markov-type probability rule.

The matrix of Markov transition probabilities is given by:

$$P = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix} \tag{1}$$

where $p_{12} = 1 - p_{11}$ and $p_{21} = 1 - p_{22}$, and subscripts 1 and 2 denote contraction and expansion, respectively. Let y_t denote the business cycle indicator and s_t denote the phase ($s_t = 1,2$). The probability density of y_t is assumed to be

$$f(y_t|s_t;\theta) = \frac{1}{\sqrt{2\pi\sigma_{s_t}}}\exp\left[-\frac{(y_t - \mu_{s_t})}{2\sigma^2_{s_t}}\right] \tag{2}$$

and P, μ_{s_t} and $\sigma^2_{s_t}$ are estimated by maximum likelihood methods.

Another version of the regime-switching model is the time-varying transition parameter model. In this model, explanatory variables are introduced as putative determinants of the transition probabilities which are now assumed to be time-varying. To ensure the probabilities are bounded between zero and one they are usually modelled as logistic functions of the list of putative explanatory variables. In this paper, y_t denotes the coincident index, and (short and/or long) leading indexes are introduced as possible explanatory variables. Probability matrix Equation 1 becomes time dependent as

$$P_t = \begin{bmatrix} p_{11t} & p_{12t} \\ p_{21t} & p_{22t} \end{bmatrix} \tag{3}$$

where $p_{12t} = 1 - p_{11t}$ and $p_{21t} = 1 - p_{22t}$. These time-varying transition probabilities are modelled as:

$$p_{iit} = \frac{1}{1 + \exp(-X_{t-1}\beta_i)} \tag{4}$$

where $X_{t-1} = (1, x_{1,t-1}, x_{2,t-1}, \ldots, x_{k,t-1})$ denotes the vector of explanatory variables which are believed to influence the transition probabilities, and β_i is a parameter vector to be estimated ($i = 1,2$). Diebold *et al.* (1991) used expected maximum likelihood (EML) method to estimate Equations 2 and 4 as a natural extension of Hamilton (1990). However, as there sometimes exists the so-called 'singularity' problem, Hamilton (1991) suggested a form of quasi-Bayesian estimation using prior estimates of the parameters. As it was felt that quasi-Bayesian estimation can sometimes be overly affected by necessarily imprecise prior information, this paper adopts constrained maximum likelihood estimation by using selected, reasonable, parameter constraints such as $\mu_1 < 0$, $\mu_2 > 0$, $\sigma_i > 0$ and so on.

Rules for dating and predicting turning points using transition probabilities

Using the estimated transition probabilities obtained from the regime switching model in combination with appropriately selected rules allows for the development of

[4] The method is not limited to two phases, but can be generalized to three or more phases. See Sichel (1994).
[5] Layton (1996) p. 421.
[6] Stock and Watson (1991, 1993) also calculated the probability of recession and expansion. However, their approach was based on defining a business cycle indicator from some individual economic variables, and the approach is different from the other probabilistic approaches referred to above.

a method for predicting the dates of turning points. This contrasts with other earlier approaches to turning point prediction which have used the estimated regime state probabilities arising from a constant transition parameter regime switching model. This paper attempts to extract useful information from the estimated time-varying transition probabilities. The switching probability from contraction into expansion, p_{12t}, is used as the basis for signals of troughs, and p_{21t}, the switching probability from expansion into contraction, is used as the basis for the signals of peaks.

In previous papers using regime state probabilities (as opposed to the transition probabilities used here) the rule adopted for dating peaks and troughs related to the state probability being above or below 0.5 (see Hamilton, 1989; Layton, 1996, 1997a). In this context, the problem is to determine a similar cut-off value for the relevant transition probability which may reasonably be regarded as high enough to be treated as a trigger signal of an imminent phase change. A natural selection is the overall long term mean value of the transition parameter.[7] This then is one aspect of the signal.

A second component of the signal addresses the issue of whether the transition probability is sufficiently large and whether it has been sufficiently large for a sufficiently long enough period. After all, given the transition probability may be expected to fluctuate around the mean over time, it does not seem sensible to use the mean as the sole signalling criterion. Thus, it is also desirable to compare the probability in any current period with that observed in some appropriate recent time period. This comparison is made by monitoring the ratio of the current transition probability to the most recent local minimum value and judge that the probability has risen enough if the ratio exceeds two. Although the threshold value of two seems to be somewhat arbitrary, some alternative values were also tested, viz. 1.5, 3.0, etc., and 2 gives the best signal for turning points. Thus, the two signal system proposed here consists of two components as follows:

$$1.\ p_{ij,t_0+s} > \bar{p}_{ij} \tag{5}$$

$$2.\ p_{ij,t_0+s}/p_{ij,t_0} > 2 \tag{6}$$

where $\bar{p}_{ij}$ is the overall (long term) mean, t_0 corresponds to the most recent local minimum value of the relevant transition parameter, $t_0 + s$ expresses the time when the signal is given, and $s \geq 5$ (explained below).

The time period, t_0, is defined as the time at which the relevant transition probability reached a local minimum. The local minimum is formally defined as

$$p_{ij,t_0} < \min(p_{ij,t_0+1}, p_{ij,t_0+2}, \ldots, p_{ij,t_0+r}) \tag{7}$$

where $r \geq 5$. The constraint $r \geq 5$ is selected to be analogous to a similar requirement in the long standing and widely-used Bry–Bochan method[8] for determining turning points and which incorporates the requirement that no phase will be recognized if it has a duration less than five months. By definition, the occurrence of the local minimum leads the signal expressed by Equations 5 and 6. Therefore, it may be regarded as the first tentative signal of an impending turning point. Of course, a signal is not formally regarded as occurring until Equations 5 and 6 also are satisfied. In real time, the formal signal cannot be recognized for at least five months after the occurrence of the defined local minimum.

In order to reduce the possibility of false signals one needs to add a caveat to the above signalling system, viz. that a potential local minimum is disregarded if it is followed by a local maximum within five months. This is also analogous to the Bry–Boschan algorithm. A local maximum at time t is defined as:

$$\begin{aligned} &p_{ij,t} > \max(p_{ij,t+1}, p_{ij,t+2}, \ldots, p_{ij,t+5}) \\ &\text{and} \\ &p_{ij,t} > \max(p_{ij,t-1}, p_{ij,t-2}, \ldots, p_{ij,t-5}) \end{aligned} \tag{8}$$

Furthermore, a rule is required for determining if and when a formal signal, having been given, should subsequently be regarded as false. This would be the case if a formal signal were given and a local maximum occurred more than five months later without a turning point being in evidence before the occurrence of the next local minimum. Finally, a turning point is regarded as missed if there is no local minimum in evidence prior to the occurrence of the turning point.

As an aside, it is recognized that, in general, Equation 8 represents a more natural definition of an extremum than is Equation 7. However, the reason for adopting Equation 7 as the definition for a local minimum, rather than an analogous version of Equation 8, is that Equation 7 results in more frequent and more sensitive turning point signals than Equation 8. It is also the case that one is only interested in monitoring for the required increases in the transition probability as described in the signalling system represented by Equations 5 and 6.

IV. EMPIRICAL RESULTS

Data

The analysis used monthly data on coincident composite indexes (CC), short leading (LD), and/or long leading (LL)

[7] As alternative rules, the mean plus one or two standard deviations were also considered. However, these alternatives were found to be less successful in dating and predicting turning points.

[8] See Bry and Boschan (1971).

composite indexes for Japan, the USA and Australia. The indexes compiled by the Economic Cycle Research Institute (ECRI) in New York are used, except in the case of the short leading indexes for Japan and Australia. As the short leading index for Japan, the leading composite index published by the Economic Planning Agency (EPA) of Japan is used and for Australia, the Westpac/IAESR leading composite index is used.

The indexes used are seasonally adjusted, but not trend-adjusted series, and are transformed to month-to-month growth rates. The sample period and descriptive statistics of CC are shown in Table 1. The means of negative growth rates and positive growth rates are quite different (as one would expect), and the variances in negative growth periods (regarded as broadly indicative of contractionary regime periods) are larger than in positive growth periods for all countries. The durations of expansions and contractions for the three countries over the sample period are shown in Table 2. In all countries, the duration of expansions is longer than that of contractions, particularly in the case of the USA and Australia. See Tables 4, 6 and 8 for the dates of peaks and troughs in each country.

Alternative versions of a time varying transitional probability model were examined, viz. as explanatory variables LD only (model 2), LL only (model 3) and both indexes (model 4) are used. The short (long) leading indexes are transformed to moving six (eight) month growth rate cumulants, i.e. for LD, $x_{t-1} = \sum_{i=1}^{6} LD_{t-i}$, for LL, $x_{t-1} = \sum_{i=1}^{8} LL_{t-i}$.[9] The span of the moving sum is expected to be the mean (or median) lead time of leading indexes.

Table 1. *Descriptive statistics of coincident indexes*

	USA	Japan	Australia
Whole sample	10/1948–5/1998	10/1965–5/1998	10/1952–5/1998
Mean	0.2538	0.1183	0.2466
Variance	0.3126	0.2929	0.2829
St. dev.	0.5591	0.5412	0.5319
Negative period*			
Mean	−0.4146	−0.3748	−0.3976
Variance	0.1754	0.2555	0.1871
St. dev.	0.4188	0.5055	0.4326
Positive period**			
Mean	0.4846	0.3989	0.4593
Variance	0.1524	0.0970	0.1323
St. dev.	0.3904	0.3115	0.3638

Notes: * for data $y_t < 0$; ** for data $y_t > 0$.

Results for the USA

Parameter estimates for the USA are shown in Table 3. Model 1 is the constant transition probability model, and is included to compare with the results of the time varying transition probability models.

Expected signs of parameters $(\beta_{10}, \beta_{11}, \beta_{12}, \beta_{20}, \beta_{21}, \beta_{22}) = (?, -, -, ?, +, +)$ and estimates in model 2 and model 3 are consistent with these expectations. In model 4, the sign of $\hat{\beta}_{21}$ is not expected and some estimates are not significant. For this model, these results are probably the result of multicollinearity between LD and LL. All estimates in model 2 and model 3 are significant and, in terms of the maximized likelihood value, model 3, i.e. using LL only, is preferred. Calculated time varying transition probabilities using model 3 are shown in Fig. 1 for $\hat{p}_{21t}$ and Fig. 2 for $\hat{p}_{12t}$.

Before applying the turning point signalling system described above, the system components are summarized here again. The first-stage signal is a local minimum defined by Equation 7, and the second-stage signal is in evidence when both Equations 5 and 6 are satisfied given the prior occurrence of the first signal. If the second-stage signal does not occur – meaning that the next local maximum defined by Equation 8 is attained before the second signal – the signal is disregarded. The number of months between the first and the second signal is required to be at least five months, and the number of months between the local minimum and the local maximum is also required to be at least five months.

Applying this signalling system, the leads and lags of the signals to the reference dates (the lead-lag table) for each

Table 2. *Months of duration of expansion and contraction*

	USA		Japan		Australia	
	Expansion	Contraction	Expansion	Contraction	Expansion	Contraction
Number	8	9	7	6	6	6
Mean	51.4	10.7	35.7	21.2	65.2	13.8
Median	42	10	28	17	48	11.5
Max.	106	16	57	36	152	26
Min.	11	6	22	9	18	8

Note: see notes of Tables 4, 6 and 8 for reference dates in each country.

[9] A number of different spans were examined for the moving sum for of the US LL data; and eight months appeared most suitable in terms of maximizing likelihood. For the justification for using moving sums, see Layton (1997b): 261–2.

Table 3. *Parameter estimates for US coincident index*

Parameter	Model 1	Model 2	Model 3	Model 4
p_{11}	0.8822 (0.0377)			
p_{22}	0.9710 (0.0090)			
μ_1	−0.3950 (0.0714)	−0.3708 (0.0752)	−0.3738 (0.0716)	−0.3638 (0.0968)
μ_2	0.4103 (0.0223)	0.4106 (0.0230)	0.4090 (0.0219)	0.4094 (0.0220)
σ_1^2	0.2839 (0.0456)	0.2954 (0.0495)	0.2950 (0.0521)	0.3056 (0.0796)
σ_2^2	0.1935 (0.0133)	0.1927 (0.0139)	0.1949 (0.0133)	0.1940 (0.0139)
β_{10}		0.9286 (0.5711)	1.8329 (0.3771)	1.1503 (0.5541)
β_{11}		−0.1074 (0.0517)		−0.0796 (0.0464)
β_{12}			−0.0602 (0.0321)	−0.0400 (0.0357)
β_{20}		3.1473 (0.3782)	4.0868 (0.5736)	3.9397 (0.6394)
β_{21}		0.0454 (0.0248)		−0.0028 (0.0331)
β_{22}			0.1409 (0.0422)	0.1329 (0.0483)
Log likelihood	−446.99	−430.58	−424.30	−421.95

Notes: The value of parentheses are asymptotic standard errors by White (1982).
Model 1: Constant transition probability model.
Model 2: Varying transition probability model using LD only.
Model 3: Varying transition probability model using LL only.
Model 4: Varying transition probability model using both LD and LL.
p_{ii}, μ_i, σ_i^2: See (1) and (2).
β_{ij}: parameter for ith phase ($i = 1, 2$) and jth explanatory variable ($j = 0$ for constant term, $j = 1$ for LD and $j = 2$ for LL) in (4).

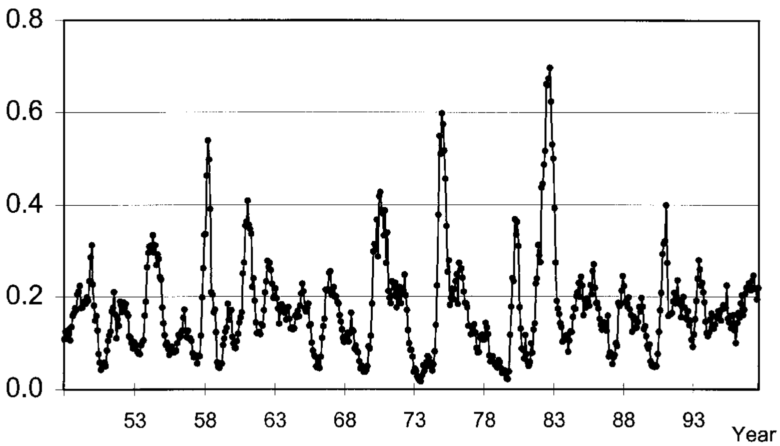

Fig. 1. *Transition probabilities from contraction to expansion by model 3: the US case* (*mean* = *0.1725*)

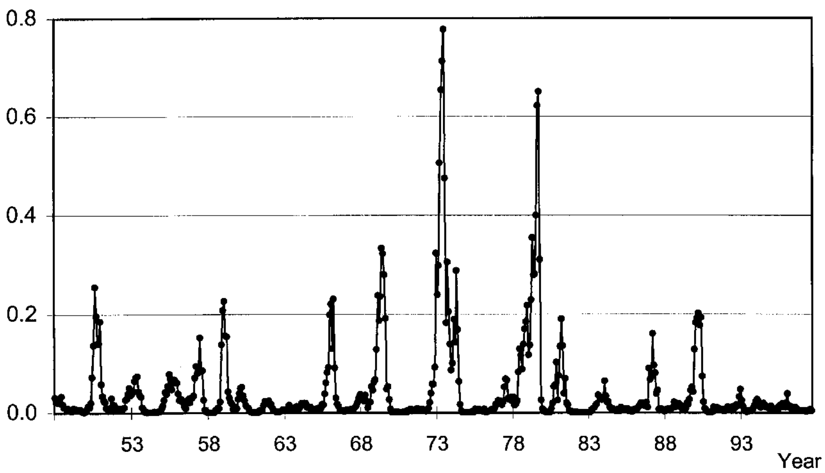

Fig. 2. *Transition probabilities from expansion to contraction by model 3: the US case* (*mean* = *0.0436*)

model is shown in Table 4. The business cycle chronology (official peaks and troughs presented in the table) is established by the business cycle dating panel convened under the auspices of the NBER. When the local maximum intervenes between the second-stage signal and the official turning point, the signal is regarded as a 'false signal'. A turning point is regarded as 'missed' if the local minimum occurs after the turning point.

Table 4. *Leads and lags of signals to US business cycle chronology*

Model	Model 2		Model 3		Model 4	
Signal	1st	2nd	1st	2nd	1st	2nd
Peaks						
Nov-1948	NA		NA		NA	
Jul-1953	−5	0	−5	+4	−5	+1
Aug-1957	+1	+6	−1	+2	−1	+4
Apr-1960	(missed)		(missed)		(missed)	
Dec-1969	−8	−3	−9	−3	−9	−3
Nov-1973	−8	−5	−10	−5	−10	−5
Jan-1980	−15	−9	−14	−9	−14	−9
Jul-1981	−5	0	−5	0	−5	0
Jul-1990	(missed)		−6	−1	−6	−1
False signals	11		4*		4	
Total signals	17		11		11	
Troughs						
Oct-1949	−5	0	−7	0	−5	0
May-1954	−5	+1	−3	+2	−5	+1
Apr-1958	−1	+4	−1	+4	−1	+4
Feb-1961	−1	+4	−2	+4	−1	+4
Nov-1970	−1	+4	−9	−2	−6	+3
Mar-1975	−1	+4	−2	+3	−2	+3
Jul-1980	−1	+4	−1	+4	−1	+4
Nov-1982	−2	+3	−11	−5	−2	+3
Mar-1991	−1	+4	−1	+4	−1	+4
False signals	0		0		0	
Total signals	9		9		9	

Notes: Models used are as in Table 3.
Figures are the number of months of signals to the turning points.
The dates of peaks and troughs are based on NBER reference dates.

All models perform well for all nine troughs. This is because the duration of contraction in the USA is quite short (as shown in Table 2) and prediction is therefore easier than in the case for peaks. The shorter duration of contractions is also reflected in Figs 1 and 2; the mean transition probability from contraction to expansion is much larger than that from expansion to contraction. For peaks, model 2 gives too many false signals. The performance of each of models 3 and 4 is almost the same but, given the aforementioned discussion of the parameter estimates, model 3 is preferred.

Now using model 3 for peaks, one peak was missed with four false signals in evidence for the remaining eight peaks. The leads are also longer than the case for troughs. This is to be expected and corresponds to the usual observation that leads at peaks are longer than those at troughs. In both peaks and troughs, the first signal always leads the turning point, but the second signal sometimes lags it, especially at troughs. In general, given all these results as described, the signalling system may be regarded as quite successful and acceptable.

Results for Japan

A similar analysis was applied to Japanese data, and the results are shown in Table 5 for the parameter estimates, Table 6 for the lead-lag results, and Figures 3 and 4 for the transition probabilities. Note that the sample periods are different between model 3 and models 2 and 4 due to availability of data. Business cycle reference dates are established by the EPA.

Table 5. *Parameter estimates for Japanese coincident index*

Parameter	Model 1	Model 2	Model 3	Model 4
p_{11}	0.9722 (0.0217)			
p_{22}	0.9825 (0.0127)			
μ_1	−0.0109 (0.0770)	−0.2975 (0.1264)	−0.0161 (0.0769)	−0.3047 (0.1132)
μ_2	0.3745 (0.0406)	0.1760 (0.0281)	0.3875 (0.0405)	0.1824 (0.0275)
σ_1^2	0.3721 (0.0159)	0.4546 (0.0336)	0.4526 (0.0451)	0.4662 (0.0365)
σ_2^2	0.2258 (0.0193)	0.1356 (0.0141)	0.2282 (0.0277)	0.1270 (0.0131)
β_{10}		3.1486 (1.2847)	3.5553 (0.7139)	2.9863 (1.5382)
β_{11}		−0.0980 (0.2678)		−0.2414 (0.5076)
β_{12}			−0.0577 (0.0954)	−0.1113 (0.2236)
β_{20}		3.5693 (0.7359)	4.0254 (0.7786)	3.4340 (0.8098)
β_{21}		0.0319 (0.1639)		−0.0818 (0.3461)
β_{22}			0.2695 (0.1088)	0.0374 (0.2094)
Log likelihood	−325.62	−177.20	−318.89	−175.14

Notes: sample period: 10/1965–5/1998 for model 1 and 3, 1/1975–5/1998 for model 2 and 4.
See notes of Table 3.

Table 6. *Leads and lags of signals to Japanese business cycle chronology*

Model Signal	Model 2 1st	Model 2 2nd	Model 3 1st	Model 3 2nd	Model 4 1st	Model 4 2nd
Peaks						
Jul-1970	NA		−9	+5	NA	
Nov-1973	NA		−10	−4	NA	
Jan-1977	−10	+5	−10	0	(missed)	
Feb-1980	−14	−3	−9	+2	(missed)	
Jun-1985	(missed)		−4	+4	(missed)	
Feb-1991	(missed)		−4	+1	(missed)	
Mar-1997	(missed)		−3	+2	(missed)	
False signls	0		2*		2	
Total signals	2		9		2	
Troughs						
Dec-1971	NA		−9	−1	NA	
Mar-1975	NA		−9	+3	NA	
Oct-1977	−2	−3	−7	−1	−7	+1
Feb-1983	−7	+4	−3	+5	−6	+3
Nov-1986	−3	+3	(missed)		−11	+4
Oct-1993	−1	+8	(missed)		(missed)	
False signals	1		2**		1	
Total signals	5		6		4	

Notes: See note of Table 4.
The dates of peaks and troughs are based on EPA reference dates.
* False signals of peak by local minimum (turning point signal) in model 3 are: Dec-1987(Nov-1988) and Sep-1994(Aug-1995).
** False signals of trough by local minimum (turning point signal) in model 3 are: Apr-1980(May-1981) and Jun-1992(Mar-1993).

From Table 5 some estimates in models 2, 3 and 4 are insignificant and, in model 4, the sign of $\hat{\beta}_{21}$ is inconsistent with expectations. In model 3, insignificant estimates are $\hat{\mu}_1$ and $\hat{\beta}_{12}$ for the contractionary regime (i.e. subscript 1) though in model 2 both $\hat{\beta}_{11}$ and $\hat{\beta}_{21}$ are statistically insignificant. This latter result implies that LD does not lead CC. It would therefore appear that model 3 is better than the other models. A possible reason for the insignificance of $\hat{\beta}_{12}$ is because the duration of contractions in Japan is substantially longer than is the case in the USA and the explanatory power of the leading index is apparently relatively much lower in contractions. This is reflected in Table 6. All seven peaks are well predicted using model 3 with no missing peaks, and only two false signals. Two official troughs are missed with two false signals for the six troughs. Unlike the USA, in the case of Japanese turning points, forecasting peaks appears to be easier than is the case for troughs. In particular, the missed troughs are the more recent ones which correspond to periods of contraction in Japan which have been relatively longer. The difference in duration between expansion and contraction in Japan is not as large as that in the other two countries under study and the mean value of the transition probabilities, p_{12t} and p_{21t}, are almost the same (see Figs 3 and 4).

The statistical insignificance of $\hat{\mu}_1$, the contractionary regime mean growth rate, might be explained by the sample period. From Table 5, it is apparent that the estimated mean derived from using either models 1 or 3 is quite different from that resulting from model 2 or 4. It is speculated that this difference arises from the different sample period used. The difference between the two periods is the period of the late 1960s and early 1970s. This period is well known to have been a period of rapid growth in Japan. In this period, even in contraction, some positive growth rates were experienced. Therefore, $\hat{\mu}_1$ in models 1 and 3, whose sample includes the period of rapid growth rates, is larger than that found from models 2 and 4, the estimation of which was based on the sample covering the period of lower overall growth rates. This result is not inconsistent with Table 2.

The difficulty in predicting troughs does not mean the signal system is without value. After all, the effectiveness of any signalling system derives from the nature of the underlying data upon which the model estimation is based.

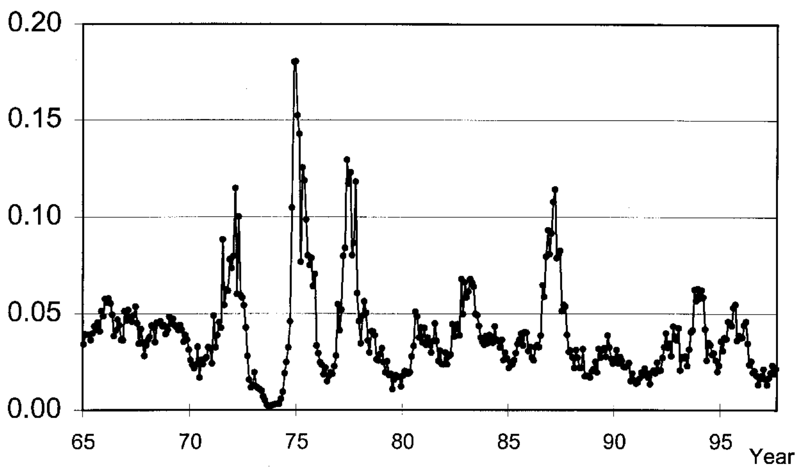

Fig. 3. *Transition probabilities from contraction to expansion by model 3: the Japanese case* (*mean* = *0.0394*)

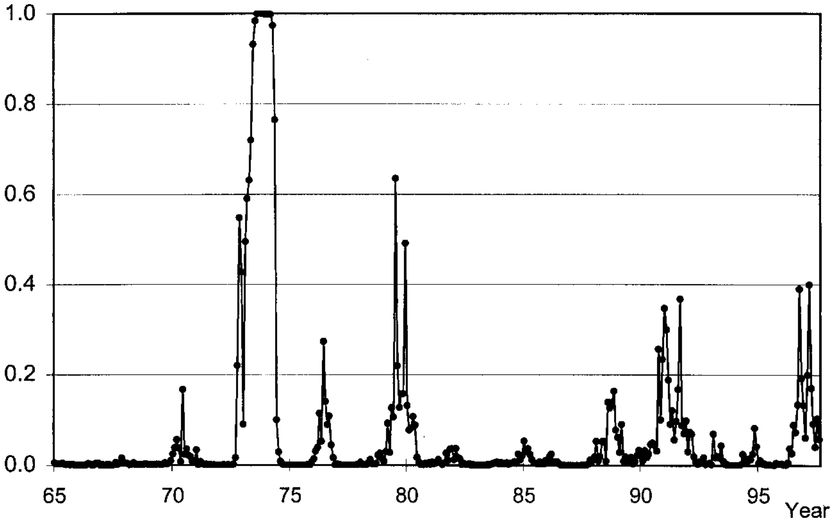

Fig. 4. *Transition probabilities from expansion to contraction by model 3: the Japanese case (mean = 0.0704)*

Results for Australia

For the Australian case, relevant tables and figures are Tables 7 and 8, and Figs 5 and 6.

The signs of all estimates are as expected. However, some estimates in model 4 are not significant, most probably because of multicollinearity. Though models 2 and 3 seem to be reasonable alternatives on the basis of estimation (although model 2 has a slightly larger likelihood), the lead-lag tables suggest model 3 is preferred for predicting turning points. Note that the defined turning points used here are not officially recognized as in the USA and Japan, because Australia does not have any official monthly business cycle chronology. The peaks and troughs are determined by applying the Bry–Boschan turning point method to the coincident series.[10] Therefore, the results might be somewhat self-fulfilling. However, the signals nonetheless show as good a performance as in the USA. This is particularly the case for troughs. This is probably also because Australian contractions are much shorter than expansions as is shown in Table 2. The longer periods of expansion provide for the possibility of more false signals in peaks.

These results for Australia provide further generality and evidence of the effectiveness of the signalling system in dating and predicting turning points, even though the targeted turning points are not officially recognized.

Predicting the next turning points

As the purpose of the proposed signalling system is to predict turning points, we now comment on the likelihood

Table 7. *Parameter estimates for Australian coincident index*

Parameter	Model 1	Model 2	Model 3	Model 4
p_{11}	0.8796 (0.0471)			
p_{22}	0.9796 (0.0104)			
μ_1	−0.2332 (0.0871)	−0.2332 (0.0825)	−0.2312 (0.0809)	−0.2246 (0.0816)
μ_2	0.3212 (0.0266)	0.3162 (0.0257)	0.3209 (0.0249)	0.3194 (0.0248)
σ_1^2	0.3888 (0.0429)	0.3884 (0.0456)	0.3877 (0.0414)	0.4033 (0.0467)
σ_2^2	0.2025 (0.0119)	0.2099 (0.0113)	0.2058 (0.0116)	0.2047 (0.0114)
β_{10}		2.1015 (0.6394)	2.5807 (0.7013)	2.4543 (0.6951)
β_{11}		−0.1920 (0.1543)		−0.0525 (0.2184)
β_{12}			−0.0865 (0.0515)	−0.0496 (0.0657)
β_{20}		4.3439 (0.8363)	5.0173 (0.3028)	4.6869 (1.3194)
β_{21}		0.6080 (0.2452)		0.0554 (0.3492)
β_{22}			0.1488 (0.0839)	0.0374 (0.1396)
Log likelihood	−407.61	−399.86	−400.19	−399.08

Notes: sample period: 10/1952–5/1998.
See note of Table 3.

[10] See Bry-Boschan (1971) and Layton (1997a).

Table 8. *Leads and lags of signals to Australian business cycle chronology*

Model Signal	Model 2 1st	Model 2 2nd	Model 3 1st	Model 3 2nd	Model 4 1st	Model 4 2nd
Peaks						
Dec-1955	−5	+5	−5	−1	−5	+5
Dec-1960	−9	0	−10	−1	−19	0
Jul-1974	−15	−6	−20	−9	−15	−7
Sep-1976	(missed)		−4	+2	(missed)	
Sep-1981	−8	+2	−8	0	−8	+2
Apr-1990	−19	−6	(missed)		(missed)	
False signals	5		6		6	
Total signals	10		11		10	
Troughs						
Aug-1956	−1	+6	−1	+5	−1	+5
Sep-1961	−4	+2	−4	+4	−4	+3
Mar-1975	−6	+1	−6	+2	−6	+2
Nov-1977	(missed)		−10	+1	−10	+1
May-1983	−14	−3	−9	−1	−9	−1
Jun-1992	(missed)		−2	+4	(missed)	
False signals	1		1		1	
Total signals	5		7		6	

Notes: See note of Table 4.
The dates of peaks and troughs are determined by Bry–Boschan methods for coincident index. See Layton (1977b).

of imminent turning points for the three countries under study. As stated earlier, and shown by reference dates, the USA and Australia are in expansion, and Japan is in contraction. Because of the size of the US and Japanese economies, the possibility of the USA falling into contraction on the one hand, and Japan pulling itself out of contraction on the other, was of worldwide concern and interest at the time this analysis was done.

Table 9 shows the transition probabilities from January 1997 to the latest period available at the time the analysis was undertaken. For the USA, there is no signal for a peak in evidence. For Australia, the first signal was given in June 1997. However, after a further 11 months, the second signal is not yet in evidence given that the level of the transition probability has been lower than the long-term mean value throughout this period. If a local maximum is attained before the second signal is given, the first signal will be disregarded. Thus, though there exists the possibility of a peak occurring in the near future, the possibility is currently very unlikely.

For Japan, December 1997 may be regarded as the first signal, but the second signal is not yet given and, if March 1998 turns out to be the local maximum (if the probabilities in the subsequent three months are lower than the value of that month), the first signal will be disregarded. Therefore, a reasonable conclusion at this point would be that a trough in the Japanese economy is not imminent. However, it should be noted that, as was described above, the signals of troughs in Japan, in particular for recent troughs, do not perform well. Of course, the available data extend only up until May 1998. This period does not include the recent economic policies – the so-called Emergency Economic Measures – viz., the permanent tax cut, the very large supplementary budget spending, bringing the Long-term Credit Bank of Japan and the Nippon Credit Bank under government control, the provision of public funds to several big banks, and so on.[11]

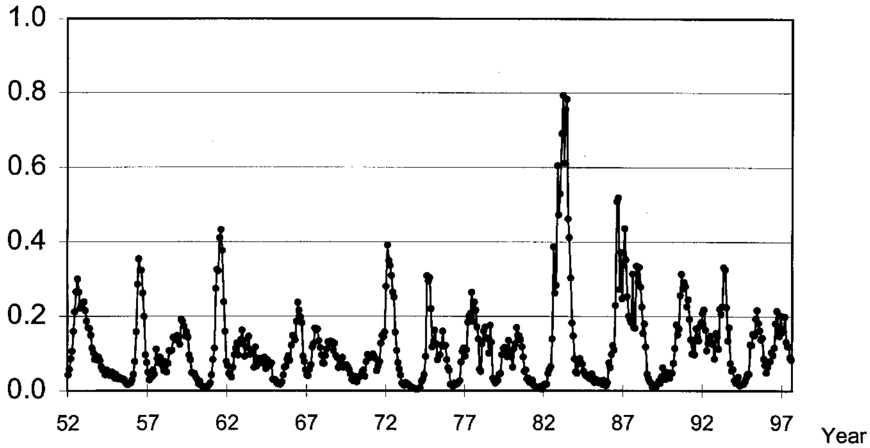

Fig. 5. *Transition probabilities from contraction to expansion by model 3: the Australian case* (*mean = 0.1195*)

[11] As it subsequently turned out, no peak was in evidence in either the U.S. or Australia throughout the rest of 1998 and 1999. The trough in Japan apparently occurred in early 1999.

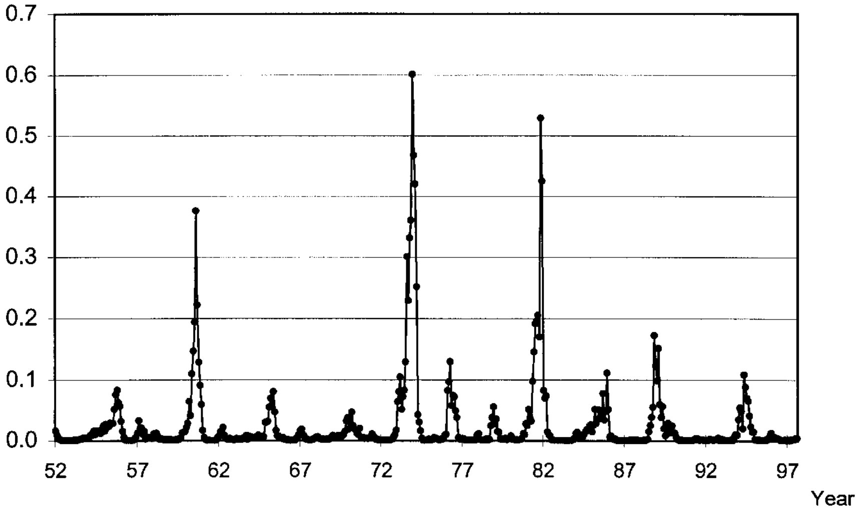

Fig. 6. *Transition probabilities from expansion to contraction by model 3: the Australian case* (*mean = 0.0246*)

Table 9. *Recent transition probabilities*

	USA	Japan	Australia
1/97	0.0121	0.0346	0.0054
2/97	0.0073	0.0236	0.0032
3/97	0.0056	0.0254	0.0037
4/97	0.0110	0.0194	0.0026
5/97	0.0091	0.0204	0.0010
6/97	0.0053	0.0177	0.0007
7/97	0.0045	0.0131	0.0013
8/97	0.0045	0.0161	0.0016
9/97	0.0039	0.0177	0.0008
10/97	0.0042	0.0212	0.0014
11/97	0.0048	0.0160	0.0014
12/97	0.0036	0.0130	0.0009
1/98	0.0032	0.0166	0.0020
2/98	0.0046	0.0193	0.0024
3/98	0.0046	0.0232	0.0024
4/98	0.0064	0.0188	0.0043
5/98	0.0045	0.0215	0.0048
mean	0.0436	0.0394	0.0246

Notes: For the USA and Australia, the figures are transition probabilities from expansion into contraction. For Japan, the figures are transition probabilities from contraction into expansion. All probabilities are estimated by model 3 for each country.

V. CONCLUSION

A new signalling system for business cycle turning points has been proposed. The system uses time varying transition probabilities arising from an estimated regime-switching model. The signalling system consists of two stages: the first is the local minimum in the relevant transition probability and the second relates to the absolute size (in relation to the overall long-term mean) and the relative level (the ratio of current probability to that of the recent local minimum) of the transition probability. Applying this system to three countries, it performs reasonably well. However, the performance in each country is sensitive to the estimation that in turn is sensitive to the duration of phases in that country. The model which includes only the ECRI long leading index (model 3) is suitable in all three countries. This means LL has predictive power as an explanatory predictor variable for business cycle turning points. And, as far as data up until May 1998 are concerned, there is no sign that a turning point will occur during 1998 in any of the three countries.

In this paper, LD and LL are used as explanatory variables in the time varying transition probability model. However, as stated earlier, the duration of phases seems also to affect the results. The influence of duration could be studied by introducing duration as an additional explanatory variable as in Durand and McCurdy (1994). And, in relation to the estimate of the contractionary regime mean growth rate in Japan, growth rates need not be classified simply into two phases, viz. contraction and expansion. Using three phases, as in Sichel (1994) and Layton and Smith (2000), is also a natural extension of this paper. Future work could involve studying whether the signalling system proposed here can be improved by utilizing such appropriately specified and estimated extended models.

REFERENCES

Bry, G. and Boschan, C. (1971) *Cyclical Analysis of Time Series Selected Procedures and Computer Programs*, Technical Paper 20, NBER, Columbia University Press.

Burns, A. F. and Mitchell, W. C. (1946) *Measuring Business Cycles*, NBER, Columbia University Press.

Diebold, F. X., Lee, J. H. and Weinbach, G. C. (1994) Regime switching with time-varying transition probabilities, in *Nonstationary Time-Series Analysis and Cointegration* (ed.) C. Hargreaves, Oxford University Press.

Durland, J. M. and McCurdy, T. H. (1994) Duration-dependent transitions in a Markov model of US GNP growth, *Journal of Business and Economic Statistics*, **12**, 279–88.

Filardo, A. J. (1994) Business-cycle phases and their transitional dynamics, *Journal of Business and Economic Statistics*, **12**, 299–308.

Hamilton, J. D. (1989) A new approach to the economic analysis of nonstationary time series and the business cycle, *Econometrica*, **57**, 357–84.

Hamilton, J. D. (1990) Analysis of time series subject to changes in regime, *Journal of Econometrics*, **45**, 39–70.

Hamilton, J. D. (1991) A quasi-Bayesian approach to estimating parameters for mixtures of normal distributions, *Journal of Business and Economic Statistics*, **9**, 27–39.

Layton, A. P. (1996) Dating and predicting phase changes in the US business cycle, *International Journal of Forecasting*, **12**, 417–28.

Layton, A. P. (1997a) A new approach to dating and predicting Australian business cycle phase changes, *Applied Economics*, **29**, 861–8.

Layton, A. P. (1997b) Do leading indicators really predict Australian business cycle turning points? *The Economic Record*, **71**, 258–69.

Layton, A. P. (1998) A further test of the influence of leading indicators on the probability of US business phase shifts, *International Journal of Forecasting*, **14**, 63–70.

Layton, A. P. and Smith, D. (2000) A further note on the three phases of the US business cycle, *Applied Economics*, **32**, 1133–43.

Neftci, S. N. (1982) Optical prediction of cyclical downturns, *Journal of Economics Dynamics and Control*, **4**, 225–41.

Niemira, M. P. (1991) An international application of Neftci's probability approach for signaling growth recession and recoveries using turning point indicators, in *Leading Economic Indicators: New Approaches and Forecasting Records*, (eds.) K. Lahiri and G. H. Moore, Cambridge University Press, Cambridge, pp. 91–108.

Sichel, D. E. (1994) Inventories and three phases of the business cycle, *Journal of Business and Economic Statistics*, **12**, 269–77.

Stock, J. H. and Watson, M. W. (1991) A probability model of the coincident economic indicators, in *Leading Economic Indicators: New Approaches and Forecasting Records*, (eds.) K. Lahiri and G. H. Moore, Cambridge University Press, Cambridge, pp. 63–89.

Stock, J. H. and Watson, M. W. (1993) A procedure for predicting recessions with leading indicators: econometric issues and recent experience, in *Business Cycles, Indicators and Forecasting*, (eds.) J. H. Stock and M. W. Watson, University of Chicago Press, pp. 255–84.

Tahara, S. (1983), *Business Cycles and Japanese Economy*, (in Japanese) Tokyo, Toyokeizaishinposha.

Wecker, W. E. (1979) Predicting turning points of a time series, *Journal of Business*, **52**, 35–50.

Zarnowitz, V. and Boschan, C. (1975a) Cyclical indicators: an evaluation and new leading indexes, *Business Conditions Digest*, March, v–xxii.

Zarnowitz, V. and Boschan, C. (1975b) New composite indexes of coincident and lagging indicators, *Business Conditions Digest*, November, v–xxiv.

Zarnowitz, V. and Moore, G. H. (1982) Sequential signals of recession and recovery, *Journal of Business*, **55**, 57–85.