Identifying Business Cycle Turning Points in Korea with a New Index of Aggregate Economic Activity

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This paper introduces a new index of aggregate economic activity in the Korean economy. The index, based on principal component analysis in combining a large data set into a single summary measure, was pioneered by the work of Stock and Watson (1999). The advantage of this index is that it can include almost all the variables needed in evaluating macroeconomic conditions, while the weight of each individual variable is determined ex post by the degree of conformity with the common latent movements of the variables. The empirical application of the new index indicates that it well reflects the official business cycle chronology of Korea set by the National Statistical Office.

At the same time, the threshold values of the new index are explored through a Monte Carlo simulation to address: (i) at what values would the new index identify the business cycle turning points correctly in a certain degree, and (ii) what would be the time lag for each value. The simulation results imply that setting the threshold values for the new index to -0.50 for the peaks and +0.20 for the troughs leads to a 76 to 87 percent success rate in identifying the business cycle turning points within a time lag of three to four months.

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I. Introduction

An accurate assessment on the current status of economic activities is a prerequisite in implementing economic policies effectively. Moreover, the importance of timely judgment of business cycle phases increases substantially if we consider the time lag between economic policies and their effects on the real economy. Nevertheless, grasping the reality of the current status of the economic activities is intrinsically tough: the business cycle is an unobservable and abstract notion, in which the whole range of economic activities, such as production, consumption, and investment, is aggregated. In addition, due mainly to increased uncertainties associated with internal and external economic environments, most economic variables tend to move in a different direction, rather than showing a uniform movement.[1)] This makes timely and accurate assessment of economic conditions all the more difficult.

In an effort to alleviate these difficulties, numerous economic indicators have been compiled, and to assess overall economic conditions. The most notable are Gross Domestic Product (GDP) statistics, which encompass the economic activities of every domestic sector. GDP has the potential to be the natural business cycle indicator considering that it includes not only production activities but also demand movements such as consumption, investment, exports, and imports. However, GDP statistics are compiled only at quarterly intervals, and even preliminary values are released almost three months after the relevant quarter has passed. To a certain degree, this lack of timeliness can be made up for by referring to the composite index of business cycle activities compiled by the National Statistics Office (NSO) each month. The composite index, nonetheless, has its own limitations: the list of component series, with its number being limited to a few variables, varies frequently; and the weight is assigned equally across all the components, thereby failing to reflect adequately their different degree of responsiveness to the business cycle.[2)]

Meanwhile, applying various econometric and statistical methods in these indicators has contributed in interpreting their movements more systematically and judging the business cycle phases in an objective manner.[3)] Since these

Notes : 1) This tendency becomes more apparent at the times of business cycle turning points, where the business cycle shifts from an upward (downward) to a downward (upward) phase.

2) In terms of its composition and compilation method, the composite index in Korea has experienced six major revisions since March 1981. The most recent revision was undertaken in February 2003.

3) Neftci (1982), Zarnowitz and Moore (1982), and Diebold and Rudebusch (1996) are seminal studies in

methods are designed to seek empirical regularities in the past, they can, in principle, be used in projecting future economic activities as well as identifying current business cycle phases. However, they also have the following disadvantages: specification of the econometric and statistical model can be set in an arbitrary way, and estimated results are subject to change with the addition of new observations. Moreover, these methods can accommodate only a few indicators such as the composite index, the production index, and the consumption index. Therefore, it cannot reasonably be claimed that the estimated results of the econometric and statistical models represent an assessment of the overall economic conditions.

Reflecting rapid advances in computing technology, statistical techniques that extract common latent movements among various business cycle indicators by principal component analysis have been developed, and applied in forecasting inflation and assessing economic conditions.[4)] This methodology appears to have a clear advantage over certain statistical indicators or other econometric models given that a sophisticated econometric analysis is applied in a data-rich environment. Stock and Watson (1999) introduced a new index of aggregate activity consisting of 168 information variables in the area of the real economy, money, interest rates, and expected inflation, and showed that the new activity index improved the performance of inflation forecasting over any other potential indicators throughout the estimation period. Since March 5, 2001, the Federal Reserve Bank of Chicago has published the Chicago Fed National Activity Index (CFNAI), which aggregates 85 real economic indicators by the Stock-Watson methodology. CFNAI is known to be especially useful in the real-time evaluation of current economic activities (Evans, *et al*., 2002).

This paper examines to what extent the new index-extracted from various economic variables covering such areas as production, consumption, investment, exports, and imports-contributes to identifying business cycle turning points in Korea. This approach appears to be meaningful considering that assessment of the current state of economic activities requires comparisons and cross-checks using numerous indicators and techniques. In addition, a Monte Carlo simulation

this area. Lee (1997), and Sung and Lee (2001) include a survey on case studies employing these techniques in Korea and other major countries.

4) Principal component analysis has been long used in finance when projecting the rate of return on equities: the first principal component of the economic and financial variables has been interpreted as a business cycle factor. Studies by Connor and Korajczyk (1986, 1988) belong to this category. On the other hand, Lee (2000) and Kim (2001) used principal component analysis in estimating a leading indicator of inflation and in deriving weights for the composite index under the condition of variable limitations.

helps the new activity index find use in the practical decision-making process by providing statistical threshold values applicable to the Korean business cycle.

The paper is organized as follows. Section Ⅱ introduces the basic concept of the new index of aggregate economic activity, which was initiated by the work of Stock and Watson (1999), and has been released as an official statistical indicator by the Federal Reserve Bank of Chicago. Section Ⅲ applies the same methodological tool in calculating the new activity index for the Korean economy, and compares the results with past business cycle events-the reference date set by the NSO. In the next section, a Monte Carlo simulation is used to analyze the index's performance in identifying business cycle turning points. Section V concludes with a summary and an outline of further research.

Ⅱ. Introducing the New Activity Index

1. Stock-Watson Method

The new activity index proposed by Stock and Watson (1999) is based on the following form of dynamic factor index model.

$$X_t = \Lambda F_t + e_t \qquad (1)$$

In the above equation, X_t is a vector comprised of economic indicators including production, consumption, and investment; F_t is a variable that captures co-movements among the indicators in X_t; and e_t is a vector that features idiosyncratic movements in each indicator. The matrix Λ can be interpreted as the sensitivity or elasticity of individual indicators to the unobservable common movement of F_t. Therefore, the value of ΛF_t derived from the process of estimating equation (1) fits naturally with the classical definition of Burns and Mitchell (1946) of the business cycle, which is that of abstract and aggregate movements occurring at about the same time in many economic activities.[5]

5) Equation (1) presupposes linearity between economic activities and their common latent movement. Since the latter variable is unobservable, statistical testing of the linearity assumption is not feasible. However, observing the proportion of how far the common latent movement explains the total variation of entire economic activities provides an indirect way of assessing the validity of the underlying assumption. In this paper, it turned out that the first principal component of a data set consisting of 31 economic indicators explained about 35 percent of the total variation.

Normally equation (1) can be cast in a state space representation form, allowing the application of the Kalman filter algorithm and maximum likelihood estimation in estimating the parameters of the equation and the realized values of the common latent variable. However, due to its nature of reiterating the process of updating and projecting the parameter values in each observation, this method can practically accommodate only about ten variables, well below the number of indicators that the policy authority usually considers in assessing current economic conditions. Stock and Watson (2002) show that principal component analysis, instead of maximum likelihood estimation, can be applied in equation (1) in extracting the common latent movement in variable X_t composed of a large number of indicators.[6] Moreover, they provide a proof that the estimated values using principal component analysis are asymptotically equivalent to the values obtained from the dynamic factor index model based on maximum likelihood estimation. Principal component analysis has an advantage of being able to extract the common latent movement under a large data set, and the result has the potential to come closer to the genuine concept of the classical definition of the business cycle. However, this method cannot exploit various specification tests on the estimated parameters that would have been available in the maximum likelihood estimation method.

In Stock and Watson (1999), new activity index is introduced that is extracted from 168 indicators in the area of the real economy, money, interest rates, and expected inflation by means of principal component analysis. In addition, this new index turned out to outperform any other variables in predicting one-and two-year ahead forecasts of U.S. inflation. Bernanke and Boivin (2003) argue that the usefulness of the new index still remains valid when the preliminary values of the indicators-that are available to the policy authority in exact form when making policy-related decisions-are used, as opposed to the revised values. They conclude that the new activity index is consistent with the way the U.S. Fed decides its monetary policy stance, which is by analyzing numerous information variables in real time.

2. Chicago Fed National Activity Index (CFNAI)

The Federal Reserve Bank of Chicago publishes the Chicago Fed National Activity Index (CFNAI): an index combining 85 monthly indicators of national economic activity, which is based on the methodology of Stock and Watson

6) [Appendix 1] provides a basic introduction on the concept of principal component analysis.

(1999).[7] The monthly value of the CFNAI is put up on the website of the Chicago Fed along with its historical series. The coverage of the CFNAI is largely confined to indicators associated with movements in the real economy: production and income (21 indicators), employment (24 indicators), investment and consumption expenditures (24 indicators), and inventory and orders (16 indicators). The CFNAI is considered to follow closely the business cycle phases in the U.S. set by the NBER.

In line with the work of Stock and Watson (1999), the CFNAI was originally designed as an experimental index to improve forecasting accuracy on inflation, rather than to evaluate overall economic conditions (Fisher (2000) and Fisher, et al. (2002)). However, the Federal Reserve Bank of Chicago developed the CFNAI as an index for identifying business cycle turning points by exploiting the property that the first principal component of the 85 indicators reflected broad economic activities. Specifically, the relationship between past episodes and the 3-month average of the CFNAI values indicated that the U.S. economy had moved into a contraction period when the CFNAI value fell below -0.70. Similarly, a value above 0.20 following a period of economic contraction strongly signaled that the economy had begun its expansionary phase. A Monte Carlo simulation exercise by Evans, et al. (2002) shows that the peak of business cycle is correctly identified with a probability of 72 percent when the CFNAI value of -0.70 is used as a threshold value.[8]

While there exist conceptual similarities between the new activity index and the composite index compiled by institutions such as the Conference Board (U.S.) and the NSO (Korea), the two indexes are different on various grounds including compilation methods. First of all, the number of indicators that can be included in the composite index is generally limited to around 10, but there is virtually no such limit in case of the new activity index. Therefore, the new activity index can accommodate almost all the indicators needed in assessing current economic conditions, while maintaining the composition of the component variables. Next, the indicators in the composite index are not weighted based on an implicit assumption that their importance is equal to each other. However, the weights in the new activity index are estimated statistically to reflect the responsiveness to the common latent movement across the

7) All the components highly correlated with future inflation according to the Bayes Information Criterion are considered to be part of the economic activity index in Stock and Watson (1999), whereas only the first principal component corresponds to the CFNAI. See Federal Reserve Bank of Chicago (2001) for more details. (http://www.chicagofed.org)

8) Section IV describes the detailed econometric specification of the stochastic simulation.

indicators.[9] The new activity index can be said to be a broader indicator than the composite index in addressing the overall extent of national economic activities.

Ⅲ. New Activity Index in Korea

1. Data Components

In constructing the new activity index in Korea, 31 indicators on domestic and overseas economy are used for the period of January 1985 to May 2003.[10] The number of 31 component series in the new activity index falls well short of other comparable indexes such as that of the CFNAI. This mostly reflects the fact that: (ⅰ) the number of indicators compiled by the statistical institution in Korea is absolutely smaller than U.S., and (ⅱ) some of the major indicators, including the estimation index of equipment investment and construction completed value, are available only after the year of 1995. Nevertheless, the 31 indicators in [Table 1] appear to represent most of the indicators that have been observed by the policy authority and major economic institutions in assessing current economic conditions.

All the indicators, except the real effective exchange rate and the OECD leading index, are seasonally adjusted, and log-differenced (or differenced) to ensure the series is stationary, if necessary. Following existing studies, each stationary series is adjusted for outliers-defined to be an observation whose distance away from the median is greater than six times the interquartile range of the series. In such cases, the original observation is replaced with the upper or lower value of the outlier criterion range, depending on the direction of deviation. As a next step, each series is standardized to have a mean of zero and standard deviation of one.

[Table 1] shows the description of the component series X_t in the new activity index, along with the value of the eigenvector corresponding to the largest eigenvalue of the second moment matrix $X_t'X_t$. Given that each individual component of principal component analysis takes the form of a linear combination between component series and eigenvectors, the value of the above

9) Typically, the indicators in the composite index also belong to the new activity index. In this case, the composite index with n indicators is a special case of the new activity index, with the weights of those indicators being $1/n$ and the other indicators being 0.

10) [Table 1] provides the detailed descriptions of the individual indicators.

Table 1 Component Data Series and Specifications

component series	unit	transformation	weight[1)]
industrial production: all industries	2000=100	log difference	0.281
industrial production: manufacturing	2000=100	log difference	0.279
industrial production: capital goods	2000=100	log difference	0.223
industrial production: consumer goods	2000=100	log difference	0.263
capacity utilization ratio: manufacturing	2000=100	log difference	0.253
inventory circulation indicator	%p	–	0.134
electric power consumption: manufacturing	10Gwh	log difference	0.186
shipment: nondurable goods	2000=100	log difference	0.206
shipment: intermediate goods	2000=100	log difference	0.248
shipment: durable goods	2000=100	log difference	0.226
shipment: machinery, domestic usage	2000=100	log difference	0.243
shipment: capital goods	2000=100	log difference	0.218
new orders: machinery, domestic usage	million won	log difference	0.075
machinery imports: excluding aircrafts	million US$	log difference	0.168
building permits: residential and commercial	1,000m^3	log difference	0.067
new orders: domestic construction	million won	log difference	0.075
wholesale and retail trade: constant prices	1995=100	log difference	0.220
overall retail trade: constant prices	1995=100	log difference	0.113
household consumption expenditures	thousand won	log difference	0.154
automobile sales: constant prices	1995=100	log difference	0.197
labor input ratio	million hours	log difference	0.124
labor entrance/separation ratio: manufacturing	%	–	0.186
employed: nonagricultural	thousand	log difference	0.174
civilian employment	thousand	log difference	0.090
unemployment rate	%	difference	-0.190
real monthly earnings: all industries	won per month	log difference	0.073
real monthly earnings: manufacturing	won per month	log difference	0.076
exports: constant prices	million US$	log difference	0.097
imports: constant prices	million US$	log difference	0.158
real effective exchange rate	1993=100	log difference	0.070
OECD leading indicator	1995-96=100	log difference	0.066

Note : 1) Value of eigenvector corresponding to the largest eigenvalue of the second moment matrix ($X_t'X_t$) of the component series X_t.

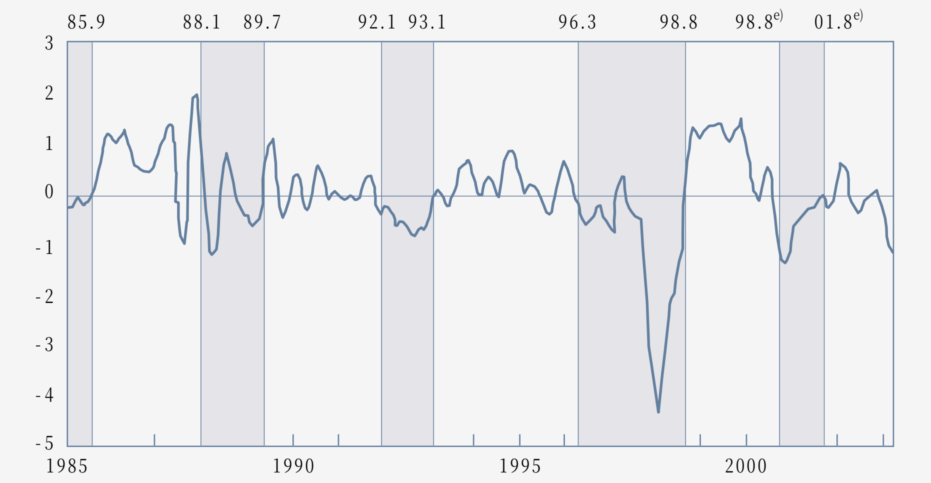
eigenvector can be interpreted as a weight on the new activity index. The estimated result shows that production-related indicators, such as industrial production, materials shipment, and capacity utilization ratio, tend to have relatively larger weights in terms of their co-movements. Specifically, weights on these indicators are three to five times larger than other indicators, implying

that each individual indicator can have a different degree of contribution in shaping aggregate economic activity. Failure to consider these differences adequately in combining the component series into a single summary measure might result in an aggregation bias.

2. New Activity Index and Business Cycle Phases

[Figure 1] plots the movement of the new activity index constructed with the combination of the weights estimated using principal component analysis and its component series.[11)] Despite conceptual differences, comparing the new activity index with the reference date in Korea seems meaningful as the new index incorporates the overall movements of 31 economic indicators.[12)] To this end, shaded areas are added in [Figure 1] to represent economic recessions. As the figure suggests, the new activity index largely has negative (positive) values on economic recessions (expansions), which is consistent with the overall economic

Figure 1 Time Trend of the New Activity Index



Note : Shaded area represents recession periods set by the NSO. The last area, in which the official dates are not yet available, is estimated from the cycle of the coincident composite index.

11) Following the convention in the CFNAI, the 3-month moving average is applied to the new activity index so as to mitigate the effects of short-run irregularities.

12) Reference date is the date of the turning points, in which the business cycle shifts from an expansion to a recession, or vice versa. The date is usually determined by a business cycle dating committee (U.S.: NBER, Japan: Cabinet Office of the Economic and Social Research Institute, Korea: NSO), following a comprehensive review and discussion among a group of experts in the field.

activity measured by the reference date.

As the case of the CFNAI illustrates, the usefulness of the new activity index can be enhanced by setting appropriate threshold values for identifying recessions and recoveries. Unlike those of the CFNAI whose series stretches back more than 35 years, however, the threshold values of the new activity index cannot be gauged from the limited occurrence of past business cycle experiences in Korea. As a preliminary step, the threshold of the CFNAI is directly applied to the new activity index, which might serve as a basis for seeking more appropriate threshold criteria in Korea.[13)]

[Table 2] shows a comparison of turning points between the reference date and the date estimated from the new activity index when the threshold values of the CFNAI are adopted without any adjustment.[14)] Although this is a rather *ad hoc* exercise, drawing only on U.S. experience, the turning points identified with the new activity index are close to the official business cycle chronology in Korea with a time lag of two to five months. This exercise illustrates the potential of the new activity index, if appropriate threshold values are attached, in making real-time assessment of the business cycle turning points as well as in evaluating current economic conditions. Nevertheless, business cycle peaks identified by the new activity index have a tendency to lag the reference date in each cyclical period, which might suggest that lowering the threshold value of - 0.7 in absolute terms would be more suitable in the Korean case.

In the case of the trough date in the 6th cyclical period, there exists a ten-

Table 2 Reference Date and the New Activity Index Date

	cyclical troughs			cyclical peaks		
	NSO	new activity index[1)]	difference	NSO	new activity index[1)]	difference
4th cyclical period	Sep. 1985	Nov. 1985	+2	Jan. 1988	Apr. 1988	+3
5th cyclical period	Jul. 1989	Jul. 1989	0	Jan. 1992	Jun. 1992	+5
6th cyclical period	Jan. 1993	Nov. 1993	+10	Mar. 1996	Aug. 1996	+5
7th cyclical period	Aug. 1998	Nov. 1998	+3	Aug. 2000	Nov. 2000	+3

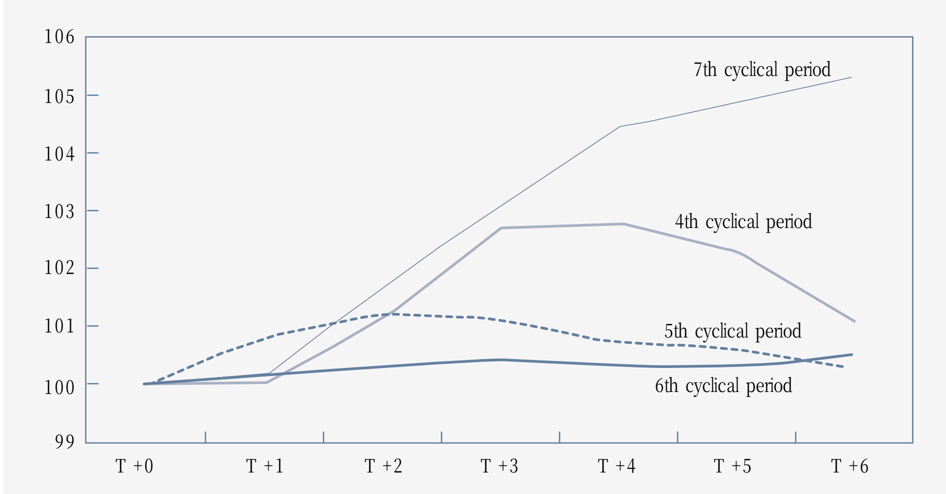
Note: 1) Identified date when the threshold values of the CFNAI are applied.

13) In Section Ⅳ, a Monte Carlo simulation is used to a more sophisticated threshold values in Korea.

14) The Federal Reserve Bank of Chicago interprets a fall in the value of the CFNAI below - 0.70 following a period of economic expansion as signifying that a recession has begun. Likewise, if the value of the CFNAI increases above +0.20 following a period of economic contraction, a recession has ended.

month gap between the reference date and the new activity index, which is quite unusual compared to other cyclical periods. The reason for this apparent anomaly seems to be the occurrence of very flat upturns at the initial stage of this cyclical period, leading to an extremely vague signal following a shift of the business cycle phases. [Figure 2] shows the pattern of the cycle of the coincident composite index for the first six months after passing the trough, with the beginning date set equal to 100.[15)] As the figure illustrates, the growth rate of the index is nearly 0 in the 6th cyclical period, while it increased at least 10 percent within two months in other cyclical periods.

Figure 2 Cycle of Coincident Index in Different Cyclical Periods



Ⅳ Estimating Threshold Values: Monte Carlo Simulation

In this section, the threshold values of the new activity index identifying business cycle phases in Korea are estimated statistically by means of a Monte Carlo simulation. Under circumstances where meaningful values are hard to obtain due to the limited experience during the construction period of the new

15) Despite differing from the new activity index in its coverage of the component series, the coincident composite index is used in comparing the speed of the recovery in periods of economic expansions. For more details of the comparison between the two indexes, please see [Appendix 2].

activity index, utilizing a method that generates an artificial Korean business cycle sufficiently appears to be a second-best solution. Moreover, a Monte Carlo simulation has its own advantage over the use of real data-it can define the reality of the business cycle, which is rather vague in the actual economy, in an explicit manner.

The overall process of stochastic simulation comprises the following three steps. A data-generating process replicating the duration and the amplitude of the Korean business cycle and 31 component series of the new activity index is specified in the first step. Then, the parameters of the econometric model of the data-generating process are estimated and calibrated. Based on the chosen parameter values, the unobservable business cycle and the 31 component series are simulated. Finally, the threshold values of the new activity index, calculated from 31 simulated series, are estimated in such a way as to signal the turning points in an accurate and timely manner.

1. Specification of the Data-Generating Process

The basic framework of the Monte Carlo simulation adheres to the work of Evans, et al. (2002). However, the stochastic simulation in this paper also considers time lag with respect to the business cycle turning points, which is neglected in the aforementioned literature. In addition, the simulation process is designed to enable the calculation of the standard errors of the threshold values.

First, the AR(1) Markov-switching model developed by Hamilton (1989) is employed to formalize the behavior of the Korean business cycle. This model has been widely used in specifying business cycles due to its property of being able to reflect the asymmetric and unobservable nature of the business cycles.

$$z_t = \mu_e + \mu_r S_t + \tilde{z}_t , \ \tilde{z}_t = \phi \tilde{z}_{t-1} + v_t \tag{2}$$

In the above equation, S_t is a Markov chain process where the value of 1 designates a recession and 0 designates an expansion. State transition probabilities are denoted as p and q: $p = \Pr[S_t = 1 \mid S_{t-1} = 1]$ represents the probability of maintaining recession in the current period given that there was a recession in the previous period. Likewise, $q = \Pr[S_t = 0 \mid S_{t-1} = 0]$ represents the probability of maintaining expansion in period t given that there was an expansion at period $t-1$. Also, both $\mu_e + \mu_r$ and μ_e are terms representing the growth of economic activity during recessions and expansions, and v_t is a white noise term with mean 0 and variance σ_v^2.

The 31 component series of the new activity index are assumed to move according to the following form of the dynamic factor index model, which has been mainly used since Stock and Watson (1989) in estimating common latent movements of major variables such as the business cycle and underlying inflation.

$$x_{it} = \gamma_i z_t + u_{it}, \ u_{it} = d_i u_{it-1} + \varepsilon_i, \ i = 1, 2, \cdots, 31 \tag{3}$$

In the above equation, x_{it} is the individual component series, and z_t is the unobservable common latent movements underlying the component series. The term u_{it} is the residual for individual series i with mean 0 and variance σ_i^2. In estimating the parameter values, equations (2) and (3) are combined as follows.

$$x_{it} = \gamma_i(\mu_e + \mu_r S_t) + w_{it}, \ w_{it} = \gamma_i \tilde{z}_t + u_{it} \tag{4}$$

2. Estimating Parameter Values and Stochastic Simulation

Setting up the parameter values is a process incorporating the main features of the Korean business cycle into the econometric model. In this regard, values are assigned by applying either sophisticated econometric techniques or simple statistics, depending on which method appears to be more appropriate given the intrinsic nature of the parameters. As a starting point, parameters μ_e and μ_r, which govern the magnitude of the business cycle, and $\Pr[S_t = 1]$ are estimated from the Markov switching model for the coincident composite index from January 1970 to March 2003, in which the method was suggested by Chauvet and Piger (2003).

In Evans, et al. (2002), they simply used the NBER's reference date and the GDP growth rate in assigning the values of the above parameters. However, the Korean business cycle appears to be more volatile, and also prone to external shocks compared to the U.S. case, leading to lower persistence with abrupt changes of direction in a short period of time. As a result, the business cycle in Korea is believed to have suffered few mini cycles over and above the official chronology. To reflect these features into the stochastic simulation, the associated parameter values need to be assigned more systematically.

The estimated results of the Markov switching model support the irregularity of the Korean business cycle. For example, the probability of being in recession, $\Pr[S_t = 1]$, approaches unity in the early 1980's and early 1990's, although these periods belong to economic expansions according to the official reference date.

Therefore, the estimated parameter values from the Markov switching model seem to reflect short run fluctuations adequately; thereby being able to produce suitable coefficients in estimating the business cycle sensitivity of the component series.

While more enhanced version of the Markov switching model, such as allowing time varying transition probability and 3-state Markov chain, can be considered, the current specification appears to be appropriate enough to simulate long run business cycle indicators-up to 170 years in this paper-mimicking the Korean experience.

The values for the state transition probabilities are set by referring the average duration of the recession and expansion, 17.5 months and 30.8 months, during the four business cycles in Korea since 1985: $p=0.9333$ and $q=0.9778$. As in the case of the realized values of S_t, these values can also be obtained from the estimated results of the Markov switching model. This, however, would result in an excessive number of cycles without properly accounting for the intrinsic nature of mini cycles.

After substituting the aforementioned parameter values in equation (4), the sensitivity of the individual variable i to the business cycle, γ_i, and the idiosyncratic movement, w_{it}, can be readily obtained by applying the Ordinary Least Squares method into the equation. Following Evans, et al. (2002), the remaining parameter values, d_i, σ_i^2, ϕ and σ_v^2, are estimated by the Simple Method of Moments (SMM) with the following set of orthogonality conditions.

$$\left.\begin{aligned} d_i &= E\left[\left(w_{it} - \frac{\gamma}{\gamma} w_{jt}\right) w_{it-1}\right] \Big/ E\left[\left(w_{it} - \frac{\gamma}{\gamma} w_{jt}\right) w_{it}\right] \\ \sigma_i^2 &= (1 - d_i^2)\, E\left[\left(w_{it} - \frac{\gamma}{\gamma} w_{jt}\right) w_{it}\right] \\ \phi &= E[w_{it}\, w_{jt-1}] \big/ E[w_{it} w_{jt}] \\ \sigma_v^2 &= \frac{(1 - \phi^2)}{\gamma^2} E[w_{it} w_{jt}] \end{aligned}\right\} \quad i \neq j \qquad (5)$$

In applying the SMM in equation (5), two instrument variables, independent to each other and reflecting the business cycle to a similar degree, are required.[16)] The two instruments selected in this paper are the shipment index of nondurable consumption goods and the total number of civilians in employment. [Table 3] reports the estimated results of the parameter values.

16) See Goldberger (1991) for more details on the SMM.

3. Identifying Turning Points

Based on the parameters associated with the Markov switching model, the business cycle realizations, S_t, are randomly generated for 2,000 observations; equivalent to about 170 years. The stochastic simulation is repeated 20 times, enabling the calculation of the standard errors. The time dimension of the random business cycle and the number of repetitions reflect the extent to which meaningful business cycle experiences and standard error estimates are obtained in the stochastic simulation.[17)] In the case of Evans, et al. (2002), the stochastic simulation is performed on a single iteration for the period of 2,000 years, or 404 business cycles. In this scheme, the computational burden is heavy, and standard errors assessing the validity of the simulation result are not available.[18)]

For the same time span of the realizations of the business cycle indicators, time series is simulated for the individual 31 component series based on the parameter values in [Table 3] and equation (4). From there, a new activity index is estimated by way of the Stock-Watson method using principal component analysis. The new activity index in each iteration is evaluated under various potential threshold values with the "true" business cycle indicator of $S_t \in \{0,1\}$, thereby being able to assess how well a specific value of the new activity index would accurately and promptly identify the turning points. The algorithm in the case of business cycle peaks works as follows.[19)] For an arbitrary value of $-r$:

[1] begin with the economy in an expansionary state;

[2] move the observation forward, and the economy is regarded to be in a recession if the value of the new activity index falls below $-r$ from above;

[3] following a shift to an increasing trend, let the new activity index pass an arbitrarily large value from below, which can be regarded to have passed the business cycle trough;[20)] and

[4] repeat steps [2] and [3] toward the final observation, and record the timing of the business cycle peaks corresponding to the value of $-r$.

The business cycle peaks judged by the new activity index are compared with the "true" peaks indicated from the realizations of S_t, which provides information

17) In actual implementation, about 30 business cycles have been generated in each repetition from the assigned state transition probability of the Markov switching model.

18) In applying principal component analysis, a square matrix of dimension 24000 24000 needs to be inverted.

19) The same procedure can be applied to business cycle troughs with a trivial modification.

20) Values of +0.40 (- 0.70) on business cycle troughs (peaks) warranted the shift of the cyclical phases without any exception.

Table 3 Estimated Parameters of the Econometric Model

1. business cycle parameters: equation (4)

$\hat{\mu}_e$	$\hat{\mu}_r$	$\hat{\phi}$	$\hat{\sigma}_v^2$
1.999	-0.845	0.712	0.880

2.parameters of indicator equations: equation (5)

i [1)]	$\hat{\gamma}_i$	$\hat{d}_i$	$\hat{\sigma}_i^2$
1	0.458	0.312	0.223
2	0.457	0.311	0.218
3	0.334	0.332	0.327
4	0.414	0.210	0.244
5	0.344	0.372	0.378
6	0.485	0.891	0.048
7	0.208	-0.036	0.440
8	0.293	0.119	0.324
9	0.364	0.486	0.321
10	0.370	0.333	0.342
11	0.296	0.435	0.291
12	0.334	0.322	0.318
13	0.082	0.154	0.476
14	0.204	0.418	0.359
15	0.107	0.218	0.449
16	0.026	0.180	0.470
17	0.248	0.512	0.322
18	0.073	0.152	0.487
19	0.114	0.432	0.391
20	0.227	0.534	0.428
21	0.207	-0.408	0.269
22	0.318	0.695	0.040
23	0.233	0.478	0.256
24	0.218	0.765	0.168
25	-0.305	0.610	0.171
26	0.050	-0.223	0.461
27	0.054	-0.169	0.471
28	0.288	0.214	0.369
29	0.254	0.462	0.404
30	-0.070	0.671	0.249
31	0.193	0.761	0.171

Note: 1) Refer to the sequence in [Table1] for the specifics of the indicators.

on the probability of properly identifying the turning points and the time lag. Repeating this process for various values of r enables calculation of the standard errors of the estimated probability and the time lag.

A. Simulation Results on Business Cycle Peaks

[Table 4] reports the result of the stochastic simulation performed for 20 times in line with the suggested algorithm. Specifically, within the range of -0.40 and -1.30, the threshold values have been adjusted by -0.10, and the ability to identify business cycle peaks along with the time lag-including forward lag-is explored for each threshold.[21)]

Table 4 Simulation Results: Business Cycle Peaks

threshold	probability that recession is correct,%	standard error	time lag, months	standard error
-0.40	84.80	4.95	2.60	0.84
-0.50	86.55	4.62	3.11	1.06
-0.60	88.00	4.90	3.73	1.23
-0.70	88.54	5.13	4.47	1.34
-0.80	89.39	4.78	5.24	1.40
-0.90	90.81	4.61	6.45	1.84
-1.00	91.46	3.74	8.35	2.22
-1.10	92.68	4.73	11.13	3.40
-1.20	93.67	4.33	14.89	4.67
-1.30	94.49	4.45	14.73	8.30

As is the case in the CFNAI, there exists a trade-off between the threshold values and the identification lag. Larger values of r in absolute terms provide higher probability of identifying a recession correctly, but at the cost of longer time lag. For instance, with a threshold of -0.40, the probability that the economy has moved into a recession within a range of 3 months is 84.8 percent, whereas the value of -0.90 yields the success rate higher than 90 percent with a time lag of 6 to 7 months.[22)]

Relatively low standard errors on the probability and the time lag enhance the reliability of the simulated estimates. Therefore, it is highly probable that the economy has passed its business cycle peak when the value of the new activity

21) Values outside the given range were meaningless due to either excessive number of crossings with the new activity index or apparent state of business cycle phases.

22) In Evans, et al. (2002), they report that the CFNAI of -1.0 leads to 85 percent probability that the recession call is correct. The difference from the new activity index in this paper appears to stem from the nature of the Korean business cycle, which is characterized by frequent ups and downs of short duration, rather than from the specification of the stochastic simulation such as the length of the simulation period.

index falls below -0.40. However, setting the threshold value at -0.50, as opposed to -0.40, would be more desirable, considering that it increases the success rate while maintaining a similar degree of time lag.

B. Simulation Results on Business Cycle Troughs

[Table 5] reports the simulation results on business cycle troughs for threshold values of *r* between 0.1 and 1.0. The fact that higher threshold values lead to accurate identification at the cost of a longer lag also holds in the case of business cycle troughs. However, at a given time lag, the extent of accurately identifying turning points is about 10 percentage points lower in the case of business cycle troughs, despite relatively larger standard errors.[23] For example, in comparing the threshold of 0.20 with -0.50 in [Table 4], both values lead to a similar time lag, but differ in terms of the success rate-the threshold of business cycle peak is larger by more than 10 percentage points than the case of the business cycle trough.

The result of the stochastic simulation suggests that in Korea identifying business cycle troughs is usually tougher than is the case for business cycle peaks. Nevertheless, the threshold value of the new activity index of +0.20 from below has a high 76 percent success rate in correctly identifying a shift to a cyclical expansion within a time lag of 3 to 4 months.

Table 5 Simulation Results: Business Cycle Troughs

threshold	probability that recession is correct,%	standard error	time lag, months	standard error
0.10	74.57	8.61	3.35	0.88
0.20	75.84	7.26	3.64	1.00
0.30	76.86	6.46	4.02	1.05
0.40	78.16	6.30	4.33	1.10
0.50	79.54	6.97	4.86	1.35
0.60	80.45	5.55	5.61	1.67
0.70	81.33	4.66	6.33	1.70
0.80	83.38	4.26	7.68	2.47
0.90	84.83	4.62	9.22	2.66
1.00	86.44	6.05	11.05	3.55

23) It is not clear whether this is also true in the U.S. case because Evans, et al. (2002) do not report the simulation results of the CFNAI's "(cpostrophe)" threshold values for business cycle troughs.

Ⅴ. Concluding Remarks

The new activity index constructed in this paper covers a wide range of economic indicators including production, consumption, investment, exports, and imports, and is believed to reflect overall economic activities well in light of previous business cycle experiences in Korea. The new index appears to be especially useful at times of business cycle turning points, when most of the economic indicators show conflicting signs. Utilizing this property would help the new activity index to assess current economic conditions in an appropriate way, thereby enhancing its role as a complementary index to existing business cycle related indexes.

At the same time, the threshold values of the new activity index are explored through a Monte Carlo simulation, providing relatively significant statistical benchmarks in identifying business cycle turning points. Setting the threshold of the new activity index to -0.50 from above indicates that there is an 87 percent probability that the economy has moved into a recession within a time lag of 3 months. Likewise, the threshold of +0.20 from below has a 76 percent success rate in identifying business cycle troughs within a time lag of 3 to 4 months.

While the new activity index is an experimental indicator with 31 component series, its usefulness as a broad economic index appears to be substantial. Nevertheless, there are some areas that need to be improved for the new activity index to better reflect the overall economic situation and to identify business cycle turning points more promptly. First of all, the set of component series comprising the new activity index needs to be reviewed, and enlarged, if necessary. In this regard, considering financial indicators such as interest rates, money supply, and equity prices to improve the assessment of economic conditions looks promising.[24] Moreover, adding indicators with little information does not have any large harmful effects on the usefulness of the new activity index, as those variables are assigned *ex post* very small weights in principal component analysis.

The result of the stochastic simulation and the statistical properties of the threshold values also need to be reviewed consistently. The simulation is based on the estimated parameters from the period since 1985, but the external crises in late 1997 must have caused a substantial shift in the pattern of economic activity in Korea. However, it is too early to incorporate such changes in the

24) However, the Federal Reserve Bank of Chicago reports that financial indicators did not change the value of the CFNAI in any significant way.

underlying parameters of the stochastic simulation. Therefore, further work on refining the parameter values is necessary in line with the extension of the time series and the accumulation of business cycle experiences.

Considering that the new activity index is a summary measure of overall economic performance, its relationship with other macroeconomic variables such as the growth rate and inflation is drawing particular attention. In addition, as Bernanke and Boivin (2003) point out in estimating the policy reaction function of the Fed, the new economic activity index can be used as an instrumental proxy characterizing the information set of the central bank.

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Appendix 1. Basic Concept of Principal Component Analysis

Principal Component Analysis (PCA) is a statistical technique designed to explain total variation of a large number of interrelated variables with a small number of factors or components. In a data-rich environment, PCA facilitates the summarization of the overall property of the entire data in an efficient way by replacing the data set with a couple of new composite variables, while the information content of the whole data set broadly remains the same.

The first principal component obtained from various macroeconomic indicators can be interpreted as business cycle movements, in line with the classical definition by Burns and Mitchell (1946): in the sense that it represents common underlying movement of major economic variables. Specifically, the new economic activity index in the paper corresponds to a linear combination of component series, in which the weight is an eigenvector of the largest eigenvalue in the second-moment matrix of the macroeconomic variables.

This process can be written into the following mathematical expressions. First, let n be the total number of indicators, and $x_t\,(1\times n)$ be the set of indicators such as industrial production, inventory index, operation ratio, and wages. For the entire sample period T, X_T is a matrix stacked with the matrix x_t.

$$X_T = \begin{bmatrix} x_1 \\ x_2 \\ \cdots \\ x_T \end{bmatrix} \qquad \text{(A.1)}$$

In the matrix above, each individual column stands for the time series of the corresponding indicator.

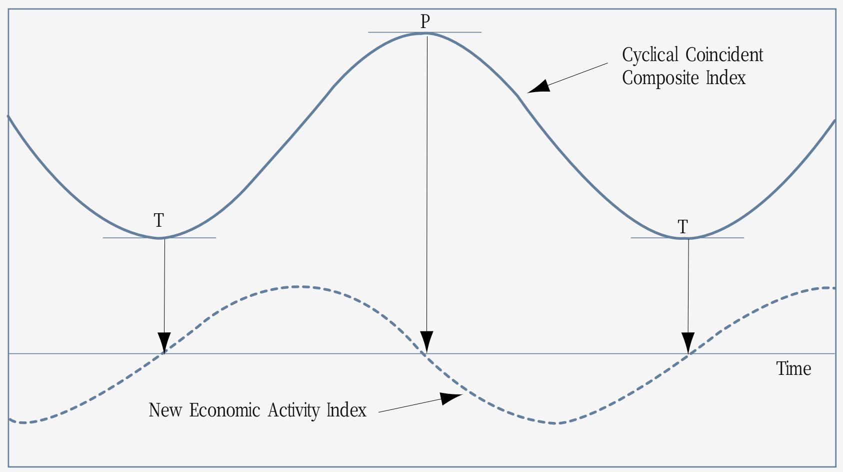
Next, the second-moment matrix $X_T'\,X_T$, representing the total variation of the X_T, is formed to derive n eigenvalues, which are all positive due to its nature of square matrix. Let the largest of these eigenvalues be $a\,(n\times 1$ vector), and the new economic activity index Y_T can be written as a following linear combination:

$$Y_T = X_T \times a \qquad \text{(A.2)}$$

Appendix 2. New Activity Index and Coincident Composite Index

The new activity index is conceptually equivalent to the cyclical value of the coincident composite index, considering that both of them are indicators to assess current economic conditions. However, in practical terms, there are

Figure A.1 Standard Pattern of the Cyclical Value of Coincident Composite Index and the New Activity Index



Note: P and T represent business cycle peaks and troughs, respectively.

substantial differences between them, especially in the areas of the object of measurement, coverage of the component series, and method of calculation. Therefore, these properties should be taken into account when comparing the two indexes.

As an illustrative experiment, assume that the reality of the business cycle can be represented as the solid line in [Figure A.1], which fluctuates according to the passage of time. The cyclical value of the coincident composite index is the level of the business cycle, whereas the new activity index is the first-order difference of the level of the business cycle.

If the business cycle is regular and symmetric as in [Figure A.1], thereby having the same duration and amplitude between expansion and recession, then the two indexes match each other in an exact way. Moreover, the peaks and troughs of the cyclical value of the coincident composite index correspond to zero values in the new economic activity index. However, the latter is not usually the case in the actual economy because the business cycle is not perfectly observable and cyclical patterns differ substantially between expansion and recession. Likewise, even the cyclical values of the coincident composite index differ among the peaks and troughs in different cyclical phases.