

The topography of leading and lagging business cycle indicators

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Abstract

Leading and trailing indexes are characterized by their timing and their accuracy. Timing is the lead or lagging (trailing) time relative to a target time series, here industrial production. Accuracy is measured here by the correspondence between the directions of changes in the indicator and the target. By plotting candidate leading and trailing time series and the target time series in phase plots (target series on x-axis) and using rotational properties of such trajectories, we found that the NBER composite leading index had lead times similar to those previously reported. From a topological map of composite as well as single leading and lagging indexes, some indexes showed unexpected properties. The interest rate spread showed a trailing pattern. The composite indicators, as well as average working hours per week and consumer price index behaved as expected. The method help characterize leading and trailing indicators.

Keywords: Business cycles; composite leading indicator, composite lagging indicator; Interest rate spread, Federal funds, money supply; Principal component analysis;

Bibliography

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Introduction

The swings in the economy over the last 60 years can be looked upon as cycles overlaid upon a trend. On top of the cycles are short term fluctuations. The troughs of the cycles represent recession periods in the economy, and anticipating these downturns is the main focus of most business cycle studies. The objective of a leading indicator is to predict the peaks and the troughs of the swings in the economy sufficiently far in advance that it is possible to react to the extreme events they represent. In practice a leading indicator is normally assumed to predict the timing of the peak less than a quarter of a cycle (that is the time between two neighbouring peaks) in advance. For example, the US industrial production shows about six peaks during the years 1955 - 1995, averaging about 7 years between peaks. The US indices of leading economic indicators typically predict peaks 2 to 14 months in advance (Newbold & Bos 1994; Filardo 1999).

The objective of this study is to characterize the leading and lagging indexes of the US business cycles. We present the results in terms of topological graphs that give the relative position of leading and lagging indexes along two axes, one representing timing (advanced warning time) and one representing accuracy. We hypothesise that leading indicators and their components will be in a different timing cluster than trailing indicators and their components. Furthermore, we hypothesise that the composite indicators outperform the single component indexes. The rationale for this second hypothesis is that none of these latter series alone contribute in a dominant or major way to business cycles. However, this conjecture is in opposition to the widely held proposition that the interest rate spread is an effective predictor of business cycle activity that dominates the predictive performance of several composite indexes ((Estrella & Mishkin 1998; Estrella et al. 2003)).

The method we use distinguishes itself from other methods in three ways. It focuses on the contemporaneous interaction between the indicator considered and the target index as opposed to leading or lagging relations between the two indexes. Second, it does not focus on the peak or trough episodes of the target index, but rather considers interactions between the series over the entire business cycle. Third, the important features of the relationships between indicators and targets are compactly summarized through principal component analysis, PCA.

Although the methodology does not lead to a direct evaluation of predictive ability, it does provide a characterization of indicators as leading, lagging, or coincident (timing). Rather than accepting prior classifications of indicators into these three categories, the timing characteristics are revealed empirically. Certain indicators previously classified as leading indicators, such as the interest rate spread, are found to be coincident or slightly lagging. The methodology also shows the consistency with which the expected relation between an indicator and the target is upheld empirically (accuracy). The characteristics of timing and accuracy are checked for robustness by separate examination of three separate time periods.

Beyond offering information on the predictive nature of business cycle indicators, this investigation provides stylized facts about relations among macroeconomic variables that are revealing about the workings of the macroeconomy. In addition, shifts in policy regimes and in macroeconomic structure may be reflected in changes in the timing and accuracy features of the relations between indicators and targets.

The rest of the paper is organized as follows. First we describe our choice of leading and lagging indexes. Thereafter we describe the method used for identifying properties of the indexes, and we describe the construction of prototypes of leading and lagging indexes against which we compare indexes reported in the literature. Lastly we discuss the findings within the framework of a forecasting taxonomy.

Materials

The business cycle literature most often employs either gross domestic product (GDP) or industrial production (IP) as a reference, or target index. We will use the term “target” index in this study. Following the OECD and to allow higher frequency data, we use US monthly data 1955- 2000 for industrial production as the target in this study. Industrial production and GDP are assumed to be coincident indicators of overall business activity. In this paper we emphasize leading and lagging indexes, although characteristics expected for coincident indicators are also presented. For the sake of convenience, we will hereafter use the term trailing index for the lagging index, to be able to use the prefix “L” for leading indexes and the prefix “T” for lagging or trailing indexes in tables and figures. We will also use the term indicators for composite measures and indexes for time series that are not constructed as a function of several independent measures. All variables used are from Economagic (2005).

The dating of recessions comes from the Business Cycle Dating Committee of the National Bureau of Economic Research (NBER). The dating committee defines a recession as a broad decline in aggregate economic activity. In their nomenclature expansions and recessions should both have a minimum length, e.g., of six months (Keilis-Borok *et al.* 2000). During the 36 year period 1960 to 1996 six recessions were defined, making the average time between recessions 5-6 years. However, the actual times between recessions vary from 1.5 years to 10 years. The recessions are shown in column 4 of Table 1. This table also contains results on advanced warning times (timing) for three models for recession predictions summarized by (Filardo 1999)).

Table 1 in here

Leading indexes. Usage of leading indexes often focuses on predicting downturns or recessions correctly. Since there may be several factors either singularly, or in concert, causing a recession, the composite leading indicators appear to be among the most widely used indicators. For leading indicators we used the composite leading indicator of the Conference Board (11 separate component indexes), and the three component indexes (weight factors in parentheses): Interest rate spread (0.329), Money supply: M2 (0.2778) and Average weekly hours (0.1963).

One rationale for using interest rate spread, defined by the Conference Board as the federal funds rate minus the 10-year Treasury bond rate (the source table shows the inverted series) is to capture policy actions of the monetary authority. When the Federal Reserve tightens monetary policy by raising the federal funds rate, while longer term rates remain relatively unchanged, the spread declines and may turn negative. The subsequent impact of the restrictive monetary policy is to slow output growth, so that decreases in the spread anticipate economic downturns. The spread index has been found by previous researchers to have strong predictive content for output growth and recessions (Estrella & Hardouvelis 1991; Estrella &

Mishkin 1998; Estrella et al. 2003). A more sceptical review of this performance is presented in Stock and Watson (2003).

The role of a monetary aggregate as a leading index, M2 in this study, dates back to earlier evidence on the relation between money and output ((Friedman & Schwartz 1963; Andersen & Jordan 1986)). Effects of money supply changes on output can be seen in traditional ISLM models of the macroeconomy. Changes in financial institutions and regulations since the early 1970s may have undermined the stability of the relation between monetary aggregates and output changes, consistent with evidence summarized in Stock and Watson (2003) and Estrella and Mishkin (1998).

The rationale for average weekly hours as a leading index is that up to some limit the working hours of people already employed can be increased or decreased relatively quickly to accommodate expected changes in output demand. Consequently, changes in weekly hours tend to precede changes in industrial production.

Trailing indexes. As trailing indicators we used the Composite Lagging index of the Conference Board (with 7 separate components) and the consumer price index for services (which has a weight of 0.1968 in the composite index). Consumer prices in general, and service prices in particular, are slow to adjust to changes in economic activity due to delays in the accumulation of information about aggregate demand changes and institutional rigidities in price adjustments (so-called menu costs).

Time windows. The time series are divided into three time windows, each containing about 200 months of observations. By using this length of time we anticipate that we will capture sufficient information on the interaction between the leading and trailing indexes, and at the same time be able to compare, in separate treatments, three different time periods. We use principal component analysis (described below) to summarize common features characterizing the relations between indicators and targets, and the changes in these relations between time periods. The first time window is from 1955 / 59 (depending on the beginning of the time series) to 1971:6 and includes two peaks that preceded two recession troughs: one recession starting in 1960:4 followed by a mini-recession in 1961:2 (not defined as a recession by the NBER) and one peak in 1969:12 followed by a recession beginning in 1970:11. The second period is from 1971:7 to 1988:2 (200 months) and includes three recessions, and the last period from 1988:3 to present includes the recession beginning in 1990:8.

Method

The method we use depends essentially on the finding that two cycling functions, when depicted in a phase plot, will rotate in a particular direction depending upon the shift in phase between the two functions. We examine this property from three viewpoints. First, we design prototype oscillating functions based on sine functions. Second, we assume that the oscillating pattern represents the interaction between two variables, and explain the rotational pattern in the phase diagram in terms of this interaction. Finally, we interpret the phase diagrams within the framework of leading and trailing indicators.

Data pre-treatment

All observed data are divided into three time windows and pre-treated to obtain comparable time series for the phase diagram analysis. Within each time window long range trends are removed by extracting the residuals from linear regressions of each series against time.

Subsequently, each time series is divided by its standard deviation. With respect to phase diagram properties, this makes the slopes and the correlation coefficient equal and the regression intercept becomes zero. These transformations make the different time series comparable in terms of rotational properties

Prototypes

Compressed and elongated sine functions have been used as a convenient representation of the medium term cycles in economies (Binner *et al.* 2005) For the sake of simplicity in constructing the prototypes, we use simple sine functions of equal wavelength. The target sine function and the assumed leading or trailing sine functions are represented by the equations:

(1) $S_1 = 1.0 \sin(\omega_t)$
 (2) $S_2 = 1.0 \sin(\omega_t + \varphi)$

where ω_t is the frequency and φ the phase shift of one the sine waves. To illustrate the expected patterns of the corresponding phase diagrams, results from four short series of paired sine functions are shown in Figure 1. One full wavelength is set to 6.28 months. To make it easier to see which way the trajectories rotate in the phase space, the first entry of the time series is set at (0,0). In this simplest illustration, neither series is generated with noise. The phase diagrams are constructed with the target on the x-axis and the indicator on the y-axis. The sine functions are shifted by three different phase shifts: zero (or a small number to avoid singularities, 0.00314), $\frac{1}{8}$ and $\frac{1}{4}$ of a wavelength. It is seen that when there is almost no time between the leading and the target series, the slope of the trajectory is almost entirely along the 1:1 axis (Figure 1c). When the leading index is $\frac{1}{4}$ wave length ahead of the target (Figure 1a), the phase diagram makes a circular rotation in clock wise direction (Figure 1b). When the trailing index lags the target by $\frac{1}{8}$ wavelength, the phase diagram is an elliptical figure that moves in a counter clockwise direction (Figure 1d).

To produce more realistic prototypes for comparison with the actual time series, nine series pairs are generated with multiplicative noise imposed on the non- target series. In the actual data covering 1955 to 2005, each sub-period of 200 monthly observations contained approximately three cycles. This means that one half wavelength of the sine function represents 33 months. We construct nine scenarios, three coinciding, or inverted coinciding series: CI(- $\frac{1}{2}$), C(0), CI(+ $\frac{1}{2}$), three trailing series: T1(- $\frac{1}{8}$), T2(- $\frac{1}{4}$), T3(- $\frac{3}{8}$), and three leading series: L1(+ $\frac{1}{8}$), L2(+ $\frac{1}{4}$), L3(+ $\frac{3}{8}$), the number in parentheses shows the phase shift in terms of wavelength fractions. The prototypes provide two characteristics of the phase diagram, the regression coefficient, or slope through the primary axis of the phase diagram, and the rotational direction. The phase diagrams are constructed with the target on the x-axis and the indicator on the y-axis as in Figure 1.

Figure 1 in here

To mimic stochastic variations we added 50% multiplicative and normally distributed random shocks to the non-target series.. The rotational direction was calculated as:

$$(3) \quad Rot = sign(\bar{v}_1 \times \bar{v}_2) \cdot Arc \sin \left(\frac{\bar{v}_1 \cdot \bar{v}_2}{|\bar{v}_1| \cdot |\bar{v}_2|} \right)$$

Where \bar{v}_1 and \bar{v}_2 are consecutive vectors in phase space formed by 3 consecutive observations.

Now, for 200 months of “observations” we calculate 198 angles of rotation. Then we calculate the overall average angle and its standard deviation, the number of angles that rotate clockwise and the number of angles that rotate counter-clockwise.

Sensitivity analysis. For the prototype shifted $\frac{1}{8}$ of a wavelength (shift = 0.785, **one wavelength is $2 \times \pi$**) the average angle for 10 series with multiplicative noise becomes -3.73, standard deviation 1.36, and 95 % confidence limit around zero of 0.84. Thus the average angle is significantly negative. The average number of positive rotations is 88.3, with a standard deviation of 4.0 and the 95 % confidence interval + 2.5. Therefore, the average number of positive rotations is significantly lower than the divide at $198/2 = 99$ positive angles. We also calculate these parameters for two stochastic parameters varying between 0 and 1.0, each of 200 observations length.

Interacting players

If we think about the sine waves as signals emanating from an unknown process, but with the knowledge that the two sine waves results from two agents that interact, it is possible to infer some information from the two signals (Sandvik *et al.* 2002). If S_1 is depicted on the x-axis and S_2 is depicted on the y-axis, then if S_2 leads S_1 , (with less than half a wavelength), S_2 can be thought of as a facilitator for S_2 , the gainer, and the rotational direction will be clockwise. An example from ecology may be illustrative. A pattern involving a facilitator agent and a gainer agent will, for example, be observed if a small shrub starts growing on an exposed cliff, providing an opportunity for slow growing trees to develop in the less exposed places sheltered by the shrub. However, as the slow growing trees develop deep root systems, they overtake the shrub (limiting light and water for the shrub) and a cycle is started. The cycle continues when the trees become old and decay and leave room for new shrub growth. The same holds for many ordinary lawn grasses; the typical seed package contains two types of grasses; one facilitator and one gainer. Starting with the growth of the facilitator, it is easy to draw the few first steps in a facilitator-gainer sequence and observe that the rotational direction will be clockwise.

A similar interaction may exist between economic variables such as the interest rate spread and the growth rate of industrial production. During an economic boom the monetary authority raises short term interest rates, with long term rates relatively unchanged, so that the spread decreases. The tightening of monetary policy subsequently lowers output growth, possibly inducing a recession. As the economy moves downwards, the central bank lowers short term interest rates, and the spread increases. This expansionary monetary policy induces a later increase in output, and the cycle repeats. The interaction between the spread and industrial production produces a pair of stochastic sine waves, with one series shifted in phase relative to the other.

Indicators and indexes

Although the leading indicators used here do not necessarily act as facilitators for our target indicator, industrial production, the cyclical interactions between the two may be similar to those described above. For example, an increase in weekly working hours may precede a rise in industrial production. We can then depict the indicator (y-axis) and IP (x-axis) in a phase plot and examine the rotational direction of the trajectories. We would anticipate that the rotational directions are clockwise. By symmetry considerations, the phase diagram for IP paired with each trailing indicator is expected to exhibit counterclockwise rotations.

To illustrate the result for the composite leading index (CLI) in the period 1955 to 1971:6, Figure 2a shows the detrended and standardized time series, and **Error! Reference source not found.**b contains the phase plot. For the phase diagram we depict the target time series, IP, along the x-axis and CLI along the y-axis. The phase plot shows an elongated time series with a regression line at an angle of 0.713 with respect to the x-axis. Starting at 1955 and calculating rotational angles between subsequent vectors we find that the overall rotation is clockwise (an average of $-17 = -36.4 + 19.5$ degrees per trajectory change, negative angles are clockwise by definition). The pattern resembles the prototype for the one-eighth cycle trailing index in Figure 1d, but with clock-wise rotation. From this comparison one would tentatively conclude that CLI is in fact a leading index that precedes movements in IP by approximately one-eighth of a cycle.

Figure 2 in here

Accuracy. We use the percentage of clockwise and counter clockwise rotations as a measure of accuracy. A high percentage of clockwise rotations would indicate a high accuracy for a leading indicator. This use is supported by the use of k-months rules for recession warnings, (Filardo 1999). The k-month rule requires the composite leading index to decline for k-consecutive months before a recession signal is sent. Now, if a recession actually occurs, a clock-wise rotation has probably occurred for k consecutive months. A second measure related to accuracy is the number of false warnings. The more false warnings a prediction algorithm give, the less accurate is the predictor (Filardo 1999: p. 40). Leading times and accuracy in the latter meaning of the term accuracy are reported to be negatively correlated. Using numbers from Filardo (1999 Table 1) (10:9; 7,4; 7,4; 4,2), the first number in each pair is the mean lead time, and the second is the number of false signals. Longer lead times give more false warnings.

Timing. We use the slope of the regression line through the points in the phase diagram as a measure of timing. Since the time series are standardized, this is equivalent to the correlation coefficient. If, for example, the leading and the target index in fact coincide, a regression between the values of the two time series would give a slope (and correlation) of 1.0 as in Figure 1d. A one-eighth wavelength trailing indicator paired with IP produces a phase diagram with a slope of 0,73, and with a clock wise rotation, **Error! Reference source not found.** d. To measure the timing in terms of months, we compare the slopes for the observed series pairs with regression coefficients for the prototype series, for which we know the timing.

Principal component analysis

The features of the phase diagrams are summarized through principal components analysis (PCA). The features are (i) average rotational direction, in degrees, (ii) average rotational direction of counter clockwise rotations only (degrees), (iii) number of clockwise rotations (%), (iv) number of counter clockwise rotations (%), and (v) average angle for non-zero clockwise rotations. These features are calculated for 27 pairs of series, in each case involving IP and one indicator or index. This provides 27 sample observations for the PCA: 9 prototype indicators, described below, plus 6 actual indicators observed over each of three time periods. The six empirical indicators are the composite leading indicator, LC (the indicator of the Conference Board with 11 components), the composite trailing indicator, TC (the lagging indicator of the Conference Board with 7 components), the interest rate spread (LS), the M2 monetary aggregate (LM), average weekly hours (LW), and the consumer price index for services (TP). The first letter in each variable name indicates a leading (L) or trailing (T) indicator as used in the business cycle literature. The empirical series will be labelled with a numerical suffix, 1, 2, or 3, to indicate the time period over which the phase diagrams are constructed.

By using principal component analysis we obtain two major plots. One is the score plot that shows the position of the samples along principal components and another is the loading plot that shows the positions of parameters. By interpreting the plots, we can infer properties of the samples.

The score plot can be regarded as a topological map of leading and lagging indicators giving the positions of the indicators relative to the fixed points of the prototypes. For example, one prototype, $L2(+\frac{1}{4})$, represents a perfect leading indicator predicting the business cycle one quarter of a cycle in advance, another, $T2(\frac{1}{4})$ represents a perfect trailing indicator which trails the business cycle one quarter of a cycle period. The coinciding or concurrent indicator, $C(0)$ matches the cycle perfectly and the indicators, $CI(-\frac{1}{2})$ and $CI(+\frac{1}{2})$ that are inverted versions of the $C(0)$ indicator are perfectly negatively correlated with IP. For the prototypes without noise the number of angles will be either 100 % clockwise or 100 % counter clockwise. The suffixes to L and T prototypes suggest progressively greater lead or trailing times.

Calculation of accuracy. Accuracy is measured along the first principal component, and we choose the index with the highest accuracy. (That is, the index with the largest percentage numbers of either clockwise or counter-clockwise rotations.) The series for the composite leading indicator, LC1 had the largest percentage of counter clock wise rotations, 61%, and a PC1 coordinate of 3.396, we choose to calculate the accuracy of any point X_i relative to this point as:

$$(4) \quad A_x = 61\% \times |X_i| / 3.396$$

Calculation of timing. If we assume that the scores for leading and trailing times for the prototypes reflect the real leading and trailing times, we can calculate the timing by examining the distances along the second principal component, PC2, from any point Y_i to the point for coincidence, $C(0)$, relative to the distance for the inverted coinciding series, $CI(\frac{1}{2})$, which we have designed to be 33 months (one-half cycle) ahead:

$$(5) \quad T_y = 33 \cdot \text{months} \times \frac{Y_i - C(0)_y}{C(0)_y - CI(1/2)_y}$$

Since a high value of both timing and accuracy is desirable, we define an overall score as the product of the two parameters, and for the sake of simplicity divided it by 100 to obtain numbers approximately in the range 0 to 10.

$$(6) \quad S = |T| \times A / 100$$

This procedure presupposes that we put equal emphasis on both parameters, which may not hold in some policy contexts. An unequal weighting of the two parameters could reflect the relative importance of each in the decision process of policy makers.

An unfortunate property of PCA plots is that axes may change direction depending upon the entries in the underlying matrix of observations. In our case the PC1 axis in Figure 4 has reversed direction in Figure 5.

Results

We first present the results for the prototypes with and without noise. Thereafter we present the results for the indicators.

The prototypes

For the nine prototypes with noise Figure 3 shows the average angle as a function of the phase shift. This graph shows that the average angle is close to zero when the two sine functions coincide (a random displacement in one direction relative to the 1:1 line in the phase diagram is offset by a random shift in the other direction). The average angles have the most extreme values when one sine function is shifted $\frac{1}{4}$ of a wavelength (+1.57) forward or backward.

 Figure 3 in here

The PCA results for the prototypes are shown in Figure 3. Without noise the accuracy measure is extreme, since all trajectories are either clockwise or counter-clockwise. When the same noise factor is applied in each case, this figure shows that the accuracy measure is most resistant to noise when phase shifts are $\frac{1}{4}$ or $-\frac{1}{4}$. The average angle is about 5.28 degrees, which is close to the expected angle when 3 full circles are made in 200 time steps: $3 \times 360 \text{ degrees} / 200 = 5.4 \text{ degrees}$. The timing feature changes abruptly from the coinciding, $C(0)$ to the inversely coinciding, $C(-\frac{1}{2})$, $C(+\frac{1}{2})$ cases. With noise the percentage clockwise and counter-clockwise rotations approach 50% each when the series are either close to coincident or one-half cycle out of phase.

 Figure 4 in here

The prototypes with stochastic component and the indicators

We experimented with several versions of the PCA using different combinations of parameters. All parameter sets that included the correlation coefficients and some measure of

average rotation gave approximately the same score and loading plots. By using only the three (two) parameters, correlation coefficient and percentage number of positive and negative rotations (the latter two being linearly dependent), the first two principal components were clearly identifiable (loading plot not shown). The first principal component represents the rotational pattern in the phase diagram, capturing the degree of accuracy (65 % explained variance). The second component represents the slope of the phase plot, expressing the timing (25 % explained variance).

We have depicted the result of the PCA plot for the composite leading and trailing indicators and selected indexes in six panels of Figure 5. The upper right panel shows the position of the prototypes (with noise). The coinciding case, $C(0)$, is at the top and the inverted coinciding case at the bottom, $CI(-\frac{1}{2})$. The difference in timing between the two cases is $\frac{1}{2}$ wave length corresponding to 33 months. Moving clockwise in this panel from $C(0)$, the phase shift increases to $\frac{1}{8}$, then $\frac{1}{4}$, and then $\frac{3}{8}$ of a cycle along an elliptical path in this diagram. Continuing clockwise along this path, the negative phase shifts of $-\frac{3}{8}$, $-\frac{1}{4}$, and $-\frac{1}{8}$ are encountered. This pattern shows the extremes in accuracy correspond to the pairs that are $\frac{1}{4}$ and $-\frac{1}{4}$ cycle out of phase with each other.

 Figure 5 in here

The leading and trailing indicators. The upper left panel shows the results for the leading, L1-L3 and the trailing, T1- T3 indicators. The dashed lines suggest a trade-off between accuracy and timing: a shorter lead time or the trailing time may be acceptable if the indicator shows greater accuracy. Positions on or outside these lines would be preferred to those inside the lines. The composite leading and the composite trailing indexes both are on the anticipated sides of the leading - trailing divide (the vertical axis). The leading index for the first period (1955- 1971), LC1, has the best accuracy (61%), but it shows a slightly shorter lead time (9 months) than LC2 for the period 1971-1988 (43% accuracy and 12 months lead time, respectively). The leading index, LC3, for the last period has both less accuracy and less lead time. The combined score for the leading indicator for the whole time series is 12, which is among the best scores obtained for all indexes examined here (Table 2).

Interest rate spread. The interest rate spread has been widely cited as a leading indicator for output growth (Estrella and Mishkin 1998; Estrella, et al. 2003). However, according to the present analysis, it appears to be a trailing index, but with relatively short lag times (3-8 months). In addition, its accuracy measure is quite low, so that its score for all three time windows ranges from 0.3 to 0.8, which is small compared to the largest score for all indicators of 6.7. The discrepancy between these results and those of the prior literature is discussed below.

Average working hours. This index is a component of the composite leading indicator. With timing measures of 9, 7, and 17 months in the three periods, and moderate accuracy ranging between 15 and 38 percent, its role as a leading index is confirmed.

Money supply. This index behaves erratically. It appears as a trailing index during the first time window (timing = -15 months), but as a leading index during the two subsequent periods (timing = 18 and 23). However, in all three time windows its accuracy is moderate, ranging between 19 and 24 percent.

Consumer price index for services. The index is a component of the Conference Board's lagging indicator and it functions well in that capacity. Timing ranges between -23 and -34 months, and accuracy is 30, 26 and 12 percent in three time windows.

Table 2 in here

Discussion

The leading and lagging (trailing) indexes for business cycles are mainly intended for prediction and diagnostic purposes. In that capacity, it is not important whether the indexes or indicators represent causal factors or are merely symptoms coming in advance of changes in business activity, and therefore useful for policy or management purposes.

The results largely supported our first hypothesis that leading and lagging indicators would cluster in different regions of a topologic map of the phase diagram characteristics. However, there are important exceptions. The interest spread, assumed in the literature to be leading, actually trails changes in industrial production. This discrepancy can be understood in terms of the dual role played by interest rates over the business cycle. When the economy expands towards capacity output levels, the central bank will tighten monetary policy to curb inflationary tendencies by raising short term interest rates. With longer term rates relative stable, the spread declines, possibly turning negative. Here the spread is seen as a lagging indicator as a result of central bank reactions to expanding economic output. Then, as the contractive monetary policy takes effect, output subsequently declines, showing the role of the spread as a leading indicator. Since previous studies have only considered this second role of the interest rate spread, these studies have searched only over positive lead times for changes in the spread relative to output. However, our methodology infers from the data whether the spread leads or lags industrial production, based on the average angle of rotation in the phase diagram. In all three time windows the rotational patterns of the phase diagrams portray the interest rate spread as a lagging index. This does not preclude its value in its second role as a predictor of output changes, but it does emphasize that the relation between the spread and industrial production involves feedback.

The second finding that is somewhat contrary to some previous studies concerns the money supply, which traditionally has been considered to be a leading index. Our methodology finds that money supply acts as a leading indicator for the latest two time windows (1971 to present), but appears to be a trailing indicator during the first period (1955 to 1971). The comprehensive review of leading indexes by Stock and Watson (2003) also found several monetary aggregates to be unreliable predictors of output growth or recessions for the US economy. Binder (2005), for example, claims that many bankers and economists now, as opposed to earlier, see long range rates as leading short rates.

Our second hypothesis, that the composite indicators would always outperform the single indexes, is not supported over all three time periods. If we use our overall score as a measure of the goodness of an indicator, then the first place among the leading indexes in time windows 1 and 2 is the composite indicator, but the first place in time window 3 is average working hours (**Error! Reference source not found.**). However, this does not necessarily imply that a composite leading indicator should be replaced by single indicators, but it would be tempting to examine all candidate leading indicators for their accuracy and timing.

Of the two trailing indexes, the consumer price index for services has the highest score in all three time windows. This is due to its large negative timing values in all three periods. The composite trailing indicator shows superior accuracy, however, in periods one and three and a tie in period two.

Our results for the lead time of the leading indicator appears to be in qualitative agreement with results on the leading indicator reported by Filardo (1999) and reproduced in our Table 1. However, estimates of actual leading and trailing times are difficult to obtain, and when reported, they sometimes appear confusing. For example, Binner and Wattam (2003, Table 2) find that unemployment leads industrial production with 10 months, but unemployment (inverted) and GDP are often said to be coincident, (Conference Board (2005: List of composite indicators), or lagging (Granger (1989,p.170). Binner and Wattam (2003) also suggest that money supply (M0, M4) either coincides, or trails industrial production, IP, with 4 to 10 months during the period 1977 to 1993, whereas we find that money supply (M2) during our two later periods leads IP by about 18 to 23 months. Elsewhere, money supply (M2) is supposed to be a leading or coincident index (Conference Board (2005: List of composite indicators); Granger (1989, p.170).

There may be several reasons for the discrepancies between the results from our analysis and those reported in the literature. Our measure of lead and trailing times considers the entire cycle period, whereas others may focus on what happens at the peak or bottom of the business cycle. It also appears difficult to make references to peaks and troughs when calculating lead and trailing times. Binner and Wattam (2003) for example, calculate the leading or trailing times by visual inspection, which probably puts emphasis on peaks and troughs. It would be interesting to examine the time series separately during periods of robust and fragile expansions and during periods of robust and fragile recessions. For example Giulioni et al. (2003) find that firms have different financial positions during the four periods, partly reflecting their access to loanable funds.

Conclusion

An examination of rotational features of phase diagrams relating indicators and targets reveals useful information about the timing and accuracy of these indicators. One innovative aspect of this methodology is the use of information on the contemporaneous relations between targets and indicators, rather than a focus on prediction over some interval. This methodology offers new insights into the behavior of some widely used indexes, such as the interest rate spread, which we find to be a lagging index. The analysis also confirms the accuracy and timing characteristics of the composite leading and training indicators, which perform consistently over the three periods studied here. A next step in this research, currently under way, is to consider whether the predictive performance of these indicators is related to the information obtained from the phase diagrams.

Literature

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Table1 Periodization of economic time series in the present study. Length of each period and recession events within each period. For the Composite Leading Indicator (CLI) rule-of-thumb model there are four versions, and we have calculated the averages for all four versions. Source: (Filardo 1999)).

Period #	Date	# M	Recession	Lead CLI rules of thumb ⁽¹⁾	Lead GDP model	NEFTCI	Average CLI, GDP and NEFTCI
1	1955/59-1971:6	150-198	May 1960; Jan 1970	9-10 (9.5) 6-7 (6.5)	16 12	7 6	9.5
2	1971:7-1988:2	200	Dec 1973; Feb 1980, Aug 1981	4-8 (4.8) 2-14 (10.8) 6-7 (6.5)	20 20 12	6 13 1	10.4
3	1988:3-1997/ 2004:9	109-200	August 1990	(-2) -14 (2.5)	none	14	8.5

(1) Four different rule of thumb for issuing advanced recession warning (2 month rule to 3 month rule, with and without threshold. See Filardo (1999) for details.)

Table 2

Timing, accuracy, and overall score for each time series and each time window. Timing is positive if the index leads industrial production, IP, and negative if it trails IP. The letter “L” in the first column shows that the index is presented as a leading index in the literature, and the letter “T” shows that the index is presented as a trailing index in the literature. Underlined numbers give highest score among leading indexes and italicized numbers give highest score among trailing indexes.

Index	Time window 1			Time window 2			Time window 3		
	Time months	Accu., %	Score	Time, months	Accu, %	Score	Time, months	Accu, %	Score
L: Leading composite	9	61	<u>5.5</u>	12	43	<u>5.1</u>	5	28	1.4
L: Working hours	9	20	1.8	7	15	1.1	17	38	<u>6.4</u>
L: Money Suppl	-15	20	3	18	19	3.4	23	24	5.3
L: Interest rate spread	-5	5	0.3	-8	10	0.8	-3	16	0.6
T: Trailing composite	-11	37	3.9	-8	26	2.0	-1	61	-0.7
T: Price index	-23	30	<i>6.7</i>	-23	26	5.8	-34	12	<i>4.0</i>

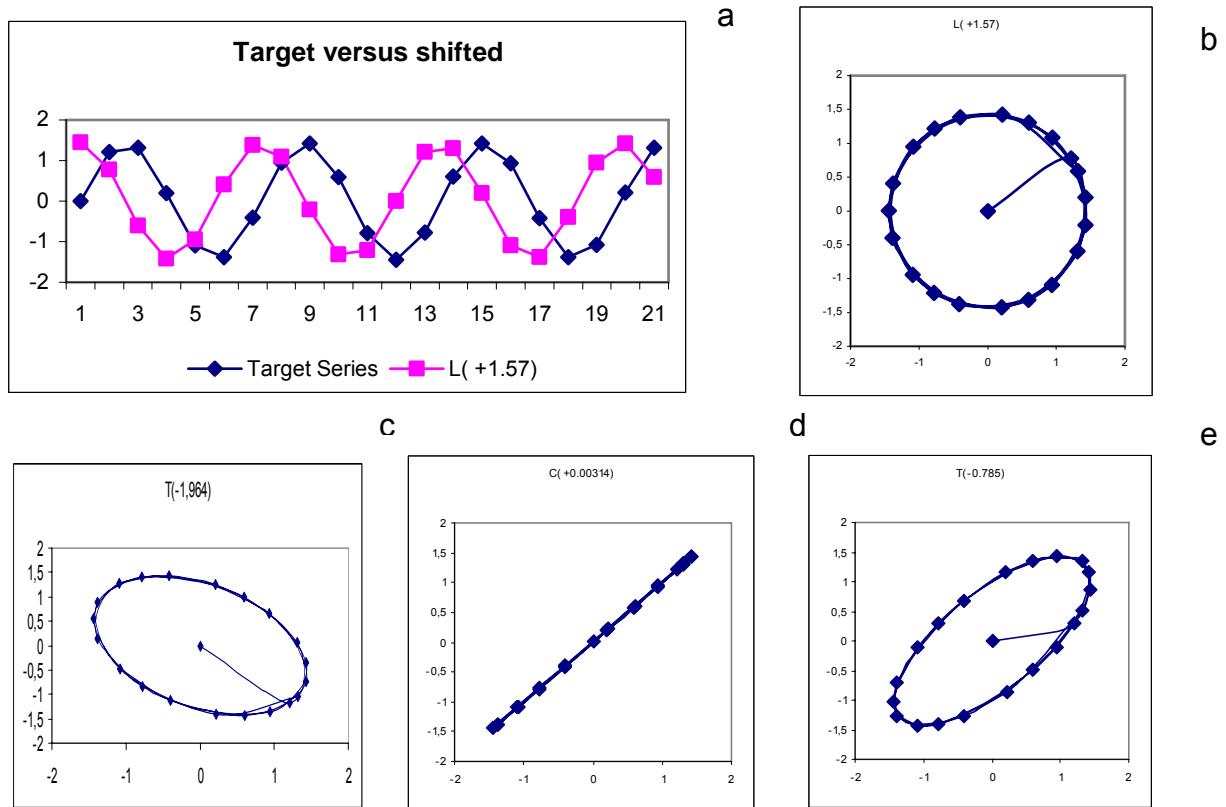


Figure 1 (a) Sine representation of a perfect business cycle (target series) and its leading indicator predicting correctly one quarter of a cycle in advance, $L(+1.57)$. In the phase portraits (a) to (d) the target series is on the x-axis and the first observation is forced to $(0,0)$ to show rotation direction. (b) Leading indicator on y-axis $L(+\frac{1}{4}$ wavelength), the phase trajectories rotate clockwise and the slope is $s = 0.0$ (c) Trailing indicator on y-axis $T(-\frac{5}{16}$ wavelength). The trajectories are rotating counter clockwise and the slope $s = -0.43$. (d) Coinciding indicator on the y-axis, $C(0.00314)$. The slope is $s = 1.0$. (e) Trailing indicator on the y-axis, $T(\frac{1}{8}$ wavelength), The phase trajectories rotate counter clockwise and the slope is $s = 0.73$.

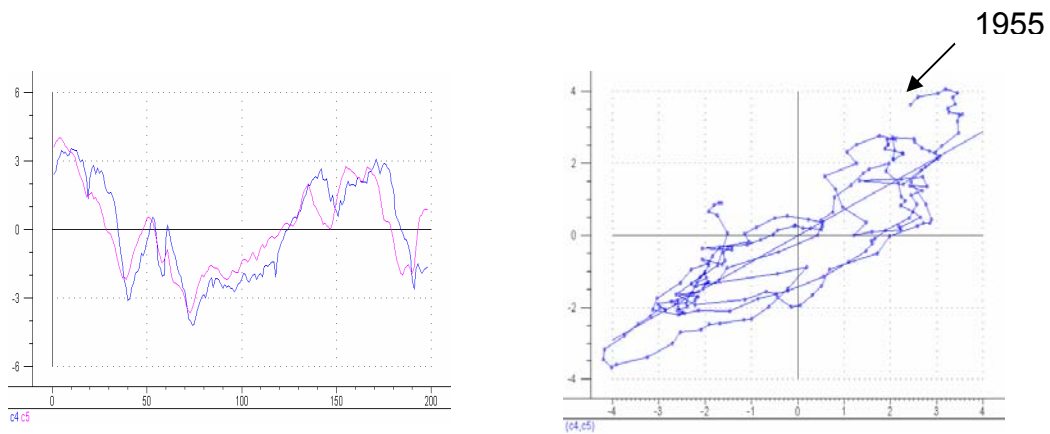


Figure 2 Time series and phase plot for composite leading indicator (NBER) and industrial production index 1955-1971. The average overall rotation for the phaseplot is clockwise.

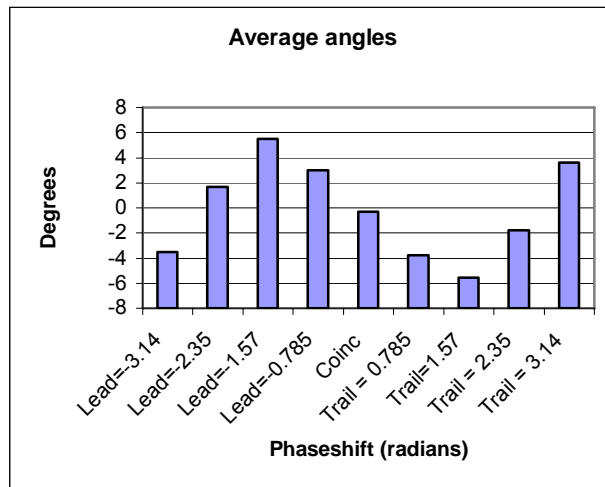


Figure 3 Phase diagram results. Average rotation of trajectories in phase diagram as a function of phase shift between two sine functions with noise added. 95% confidence limits for Trail = 0.785 is 0.8 units.

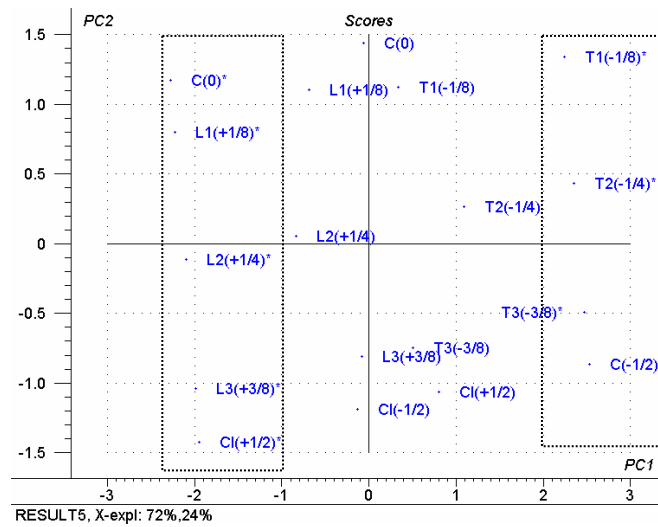
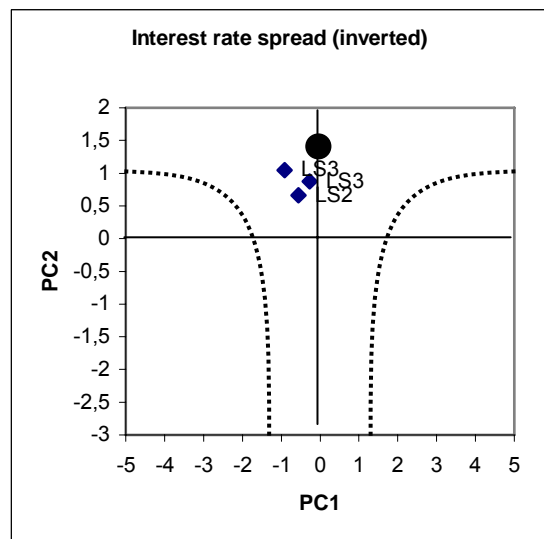
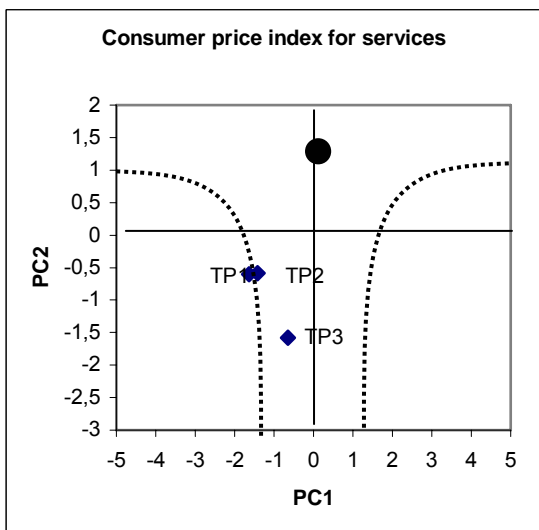
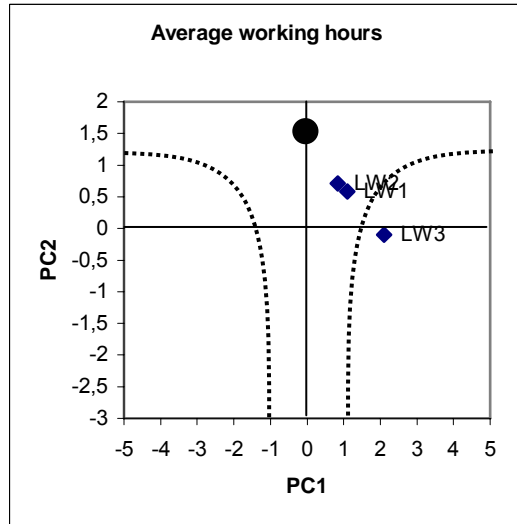
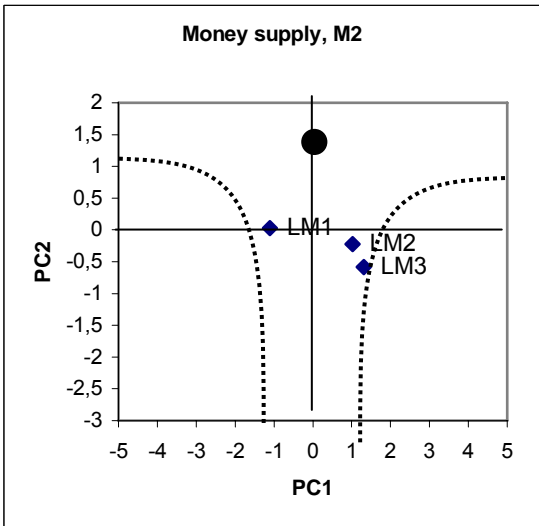
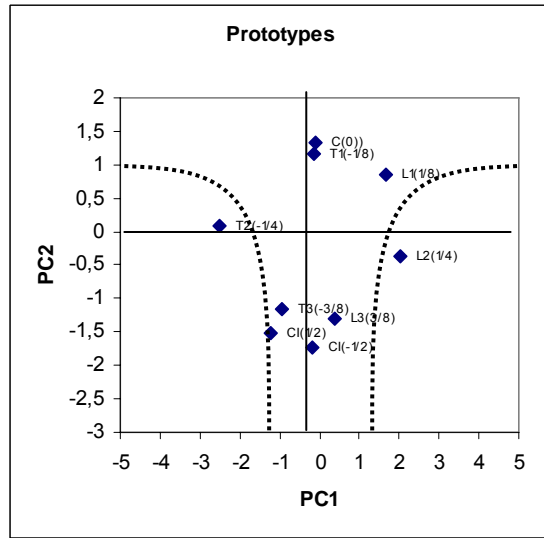
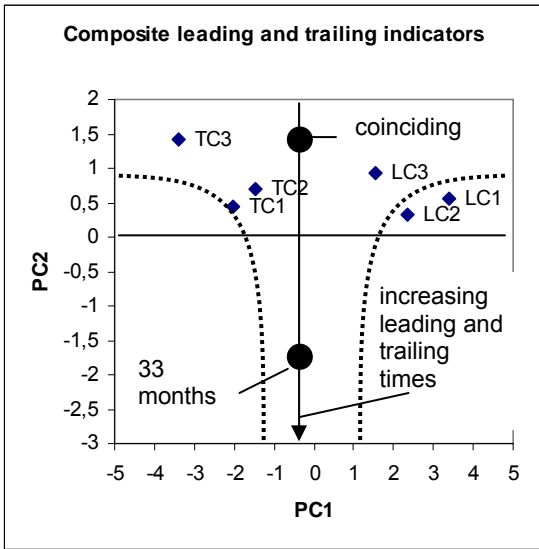


Figure 4 Phase diagram for prototypes with and without noise. Legends with stars represent no noise prototypes and legends without stars represent prototypes with 50 % multiplicative noise added. The position of the former is outlined with stippled squares. L indicates leading series, T are trailing series, suffixes indicate leading or trailing times and numbers in parentheses shows phase shifts relative to the target series as fractions of a wavelength.



← Trailing Accuracy Leading →

← Trailing Accuracy Leading →

Figure 5 Topological maps of leading and trailing indexes. The y-axis of this PC score plot corresponds to timing; the longer the distance from the coincidence point, the longer the leading or trailing times. The x-axis corresponds to accuracy, the further from origin, the higher the accuracy. For trailing indexes accuracy increases to the left; for leading indexes accuracy increases to the right. T = trailing, L = leading; 1, 2, 3 = time windows. C = composite index, M = Money supply, W = Average working hours, P = Consumer price index; S = Interest spread. See text