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# A New Index of the Business Cycle

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Abstract

The authors introduce a new index of the business cycle that uses the Mahalanobis distance to measure the statistical similarity of current economic conditions to past episodes of recession and robust growth. Their index has several important features that distinguish it from the Conference Board's leading, coincident, and lagging indicators. It is efficient because as a single index it conveys reliable information about the path of the business cycle. Their index gives an independent assessment of the state of the economy because it is constructed from variables that are different than those used by the NBER to identify recessions. It is strictly data driven; hence, it is unaffected by human bias or persuasion. It gives an objective assessment of the business cycle because it is expressed in units of statistical likelihood. And it explicitly accounts for the interaction, along with the level, of the economic variables from which it is constructed.




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**A NEW INDEX OF THE BUSINESS CYCLE**

We introduce a new index of the business cycle that is based on a statistic called the Mahalanobis distance. This statistic was introduced originally in 1927 and modified in 1936 to analyze resemblances in human skulls among castes in India.[1] It was rediscovered independently in 1999 to measure turbulence in the financial markets,[2] and it has since been applied to diagnose diseases and to detect anomalies in self-driving vehicles. We apply the Mahalanobis distance to measure the similarity of a set of economic variables to past episodes of recession and robust growth.

We proceed as follows. We first describe the Mahalanobis distance as it was originally conceived by Mahalanobis to analyze human skulls. We then explain how we adapt it to create an index of the business cycle. Next, we provide empirical evidence of our index's effectiveness in assessing the state of the economy. We conclude with a summary of our analysis. We also include two appendices; one which describes the methodology used by the NBER to measure the business cycle, and one which describes the methodology used by the Conference Board to construct their economic indicators.




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**The Mahalanobis Distance as Originally Conceived**

The Mahalanobis distance was originally conceived to measure the statistical similarity of the values of a set of dimensions for a given skull to the average values of those dimensions for a chosen group of skulls. It is given by Equation 1.

$$d = (x - \mu)\,\Sigma^{-1}(x - \mu)' \qquad (1)$$

In Equation 1 $d$ equals the Mahalanobis distance, $x$ equals the values of a set of dimensions used to characterize a skull, $\mu$ equals the average values from a chosen group of skulls, and $\Sigma^{-1}$ equals the inverse of the covariance matrix of the group's dimensions. The term $(x - \mu)$ captures how similar each dimension, by itself, is to the group's average values. By multiplying $(x - \mu)$ by the inverse of the covariance matrix, it captures how similar the co-occurrence of the dimensions is to their co-occurrence in the group. This multiplication also converts the variables into common units. This feature is not important in analyzing human skulls because all the variables are measured in the same units, centimeters. When we apply this formula to create an index of the business cycle, however, this feature is very handy because some of the variables we use are measured as percentage changes whereas others are measured as levels.




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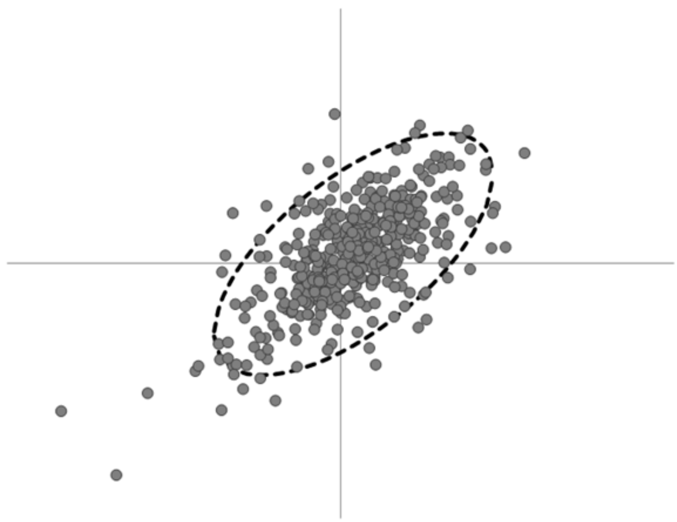
Exhibit 1 helps us to visualize the Mahalanobis distance.

Exhibit 1: Scatter Plot of two Hypothetical Skull Dimensions



In Exhibit 1 the dots represent values of the two dimensions for various skulls. The center of the ellipse represents the average values of the two dimensions for a chosen group of skulls. The observations within the ellipse represent values of the two dimensions that are more plausible given that chosen group. The observations that lie outside the ellipse represent values that are less plausible. Notice that some observations within the ellipse at either of the narrower ends are further from the center than some observations that lie outside the fatter part of the ellipse. These latter observations are less plausible because one dimension was below average while the other was above average even though these dimensions are positively correlated as evidenced by the positive slope of the observations. This illustrates the importance of accounting for the co-occurrence of the observations. It is important to note

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that all the observations on a given ellipse have the same Mahalanobis distance even though they have different Euclidean distances from the center.

In a nutshell, the Mahalanobis distance accounts for a couple of important features of statistical similarity. It scales each value of the chosen observation by the variability of the values in the group, which has the added benefit of converting all values into common units. And it accounts for the co-occurrence of the values for a given observation.

## An Index of the Business Cycle

We now apply the Mahalanobis distance to create an index of the business cycle. In this application, the observations are the values of a set of economic variables, and the groups are the values of these variables during periods of recession or robust growth. Within this context, we redefine the Mahalanobis distance as shown in Equation 2.

$$d = (x - \mu)\, \Sigma^{-1}(x - \mu)' \qquad (2)$$

In Equation 2 $d$ equals the Mahalanobis distance, $x$ equals the values of a set of economic variables at each point in time, $\mu$ equals the average values of those variables during past episodes of recession or robust growth, and $\Sigma^{-1}$ equals the inverse of the covariance matrix of those values during periods of recession or robust growth. Whereas Mahalanobis sought to determine if a set of dimensions for a skull was more plausibly associated with one caste versus another, we seek to determine if the values for a set of economic variables are more closely associated with the values that prevailed during past recessions or periods of robust growth.




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We focus on robust growth rather than growth because it is important that the regimes be symmetrically opposite each other and sufficiently separated from each other.

Data and Methodology

We construct our index using the following economic variables starting in January 1916 and ending in November 2019:[3]

- Industrial Production (one-year percentage change, measured monthly)
- Nonfarm Payrolls (one-year percentage change, measured monthly)
- Return of the Stock Market (one-year return, measured monthly)
- Slope of the Yield Curve (10-year rate minus the Federal Funds Rate)

We define recessions as those periods identified as recessions by the NBER. We define periods as robust growth as months in which the year-over-year percentage change in industrial production ranked above the 75th percentile relative to the prior 10 years. This tail of the growth distribution is approximately proportional to the recession tail. For the first five years of our sample we use a threshold of 5% annual growth in industrial production. We then proceed as follows.

1. We isolate two sub-samples from the historical observations starting in January 1926: those that qualify as recessions and those that qualify as robust growth. The data prior to 1956 includes revisions that were not available at the time. For each month starting in January 1956, we only use data (including prior revisions) that were available at that point in time.
2. We then calculate the means and covariances for each sub-sample.




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3. Next, we calculate the Mahalanobis distance of each month's observations from each sub-sample.
4. We convert these distances, $d$, into likelihoods, $l$, using the multivariate normal probability density function (PDF) as shown. In this formula, the covariance matrix $\Sigma$ equals that of the sub-sample for which we are measuring distance and likelihood.

$$l(d) = (\det(2\pi\Sigma))^{-1/2} e^{-d/2} \tag{3}$$

5. We rescale the likelihood of recession by dividing it by the sum of the recession and robust growth likelihoods. We interpret this rescaled likelihood of recession as a probability.
6. We repeat this process for each month of our sample.

**Results**

We now present evidence of the effectiveness of our index. It is important to keep in mind that the identification by our index of recessions is not self-fulfilling because we use different variables to construct our index than the NBER uses to identify recessions. This is not so of the Conference Board's Index of Coincident Indicators. The NBER defines a recession as "a period of falling economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales." With the exception of GDP, these indicators match the four variables that make up the Conference Board's Index of Coincident Indicators. Therefore, the Conference Board's




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indication of a recession is self-fulfilling because the NBER identifies a recession based largely on the same variables the Conference Board uses to indicate a recession.

Exhibit 2 presents a time series of our index of the business cycle (solid black line), which we refer to as the KKT Index, beginning in January 1956 and ending in November 2019 (the period for which all observations are out of sample). This line measures how much more likely it is that the conditions at any point in time are associated with recession instead of with robust growth. The periods defined as recessions by the NBER are indicated by the shaded bars. As of November 2019, the value of the KKT index was 76% (left axis), which means that considering either recession or robust growth, this set of conditions is more closely associated with recession 76% of the time (and with robust growth 24% of the time). Put differently, a recession is more than three times as likely as robust growth. An index level of 76% does not necessarily mean that the economy is currently in recession. Rather, we should interpret it as an indication of the potential for the economy to enter recession in the foreseeable future. Given historical guidance, the index should be close to 100% when a recession is imminent or underway.

The dashed line shows the Conference Board's Index of Coincident Indicators.[4] This time series begins in January 1982, and its values are indicated by the right axis. A value of 0 indicates neutral economic conditions, whereas large negative values coincide with recessions. (We inverted the scale to coincide with the KKT Index.)




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Exhibit 2: KKT Index and Conference Board Index of Coincident Indicators

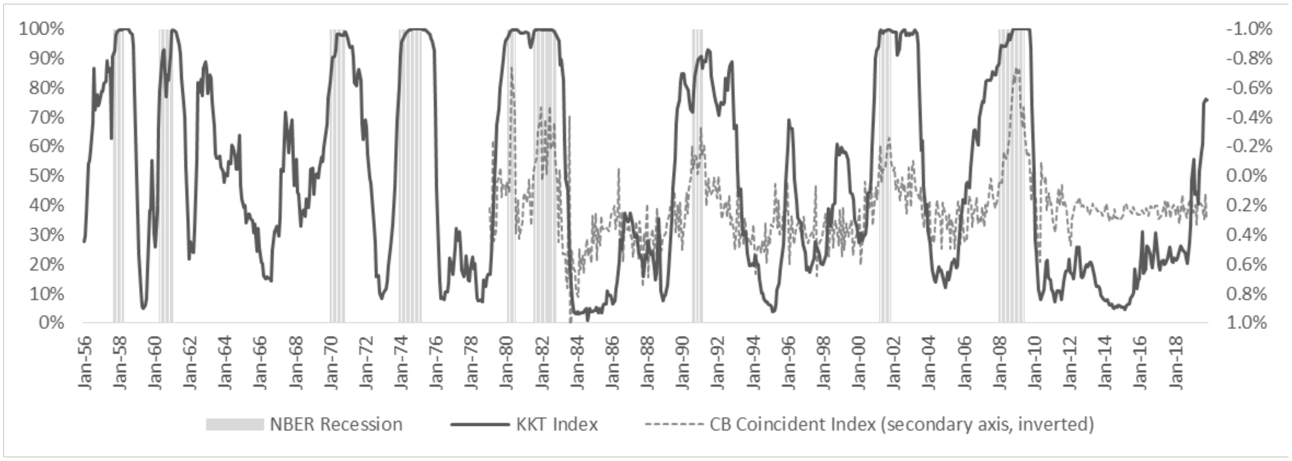


Exhibit 3 shows the KKT Index of the Business Cycle alongside the Conference Board's Index of Leading Indicators.

Exhibit 3: KKT Index and Conference Board Index of Leading Indicators

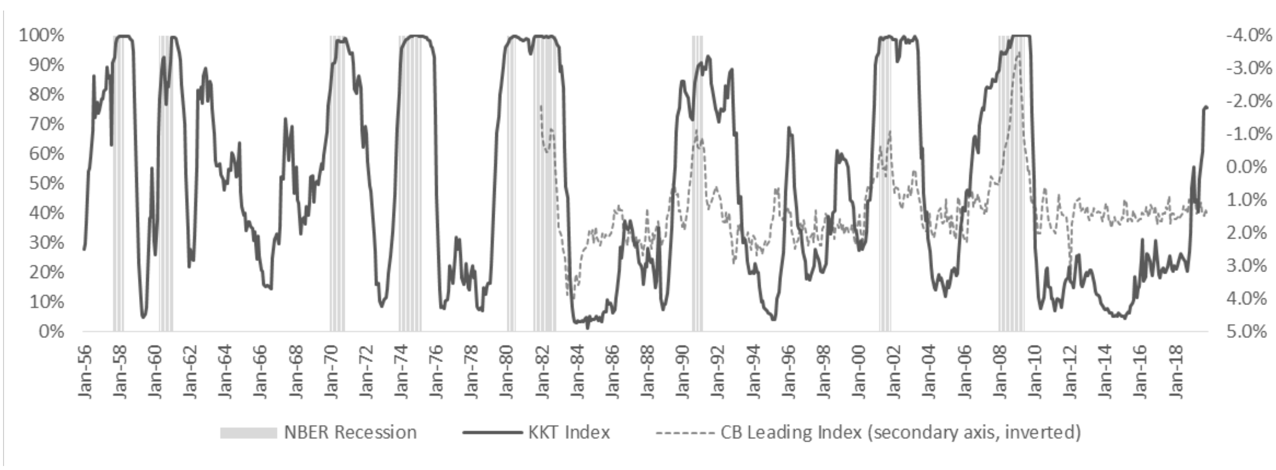





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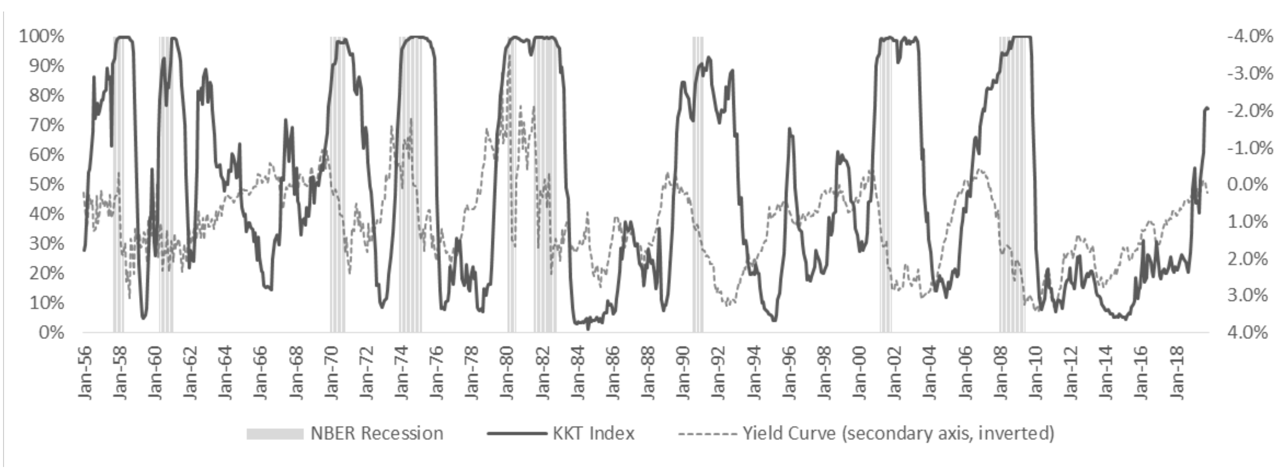
Exhibit 3 indicates that the Conference Board's Index of Leading Indicators tends to coincide with recessions rather than anticipate them. The KKT Index rises leading up to every recession so that the combination of its trajectory and level provides a reliable indicator of the likelihood recession. As of late 2019, the Conference Board's Index of leading Indicators shows a significant discrepancy with the KKT Index. Whereas the KKT Index has spiked recently, the Conference Board's Index of Leading Indicators has remained flat.

Exhibit 4 compares the KKT Index to the yield curve, which we define as the 10-year rate minus the Federal Funds Rate. Many pundits believe that an inverted yield curve presages the onset of recession. Exhibit 4 tends to support this relationship, though the lead time is often quite long.

Exhibit 4: KKT Index and the Yield Curve




We next present an event study of the KKT Index of the Business Cycle. The shaded bar in Exhibit 5 represents the events which are either recessions or periods of robust growth that

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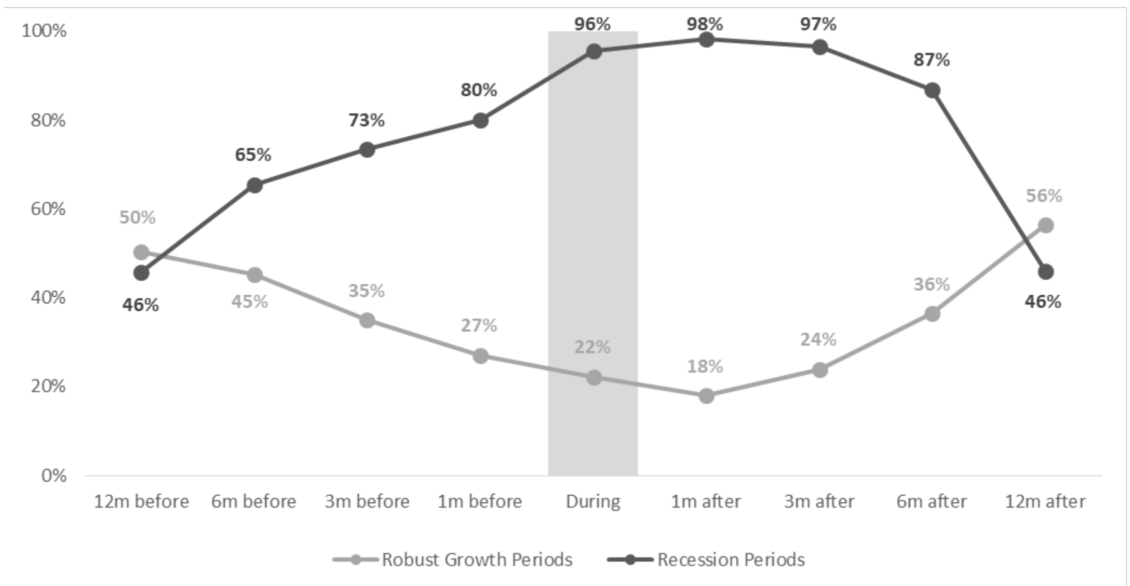
occurred since 1956. The width of the bar is not relevant. These events varied by duration. The left side of the bar represents the beginning of the events while the right side represents the end of the events, irrespective of their durations.

Exhibit 5: KKT Event Study




The dark line shows the level of the KKT Index leading up to, during, and following recessions. The light line shows level of the index leading up to, during, and following periods of robust growth. We define robust growth events based on annual changes in real GDP, taking into account revisions.[5] Because our index is constructed as the relative likelihood of recessions, we should expect it to be low during periods of robust growth, which it is.

Exhibit 5 reveals a stark separation in the level of the KKT Index depending on whether it is measured around recession events or robust growth events. It also reveals that the extreme levels of the index tend to persist for a few months following the conclusion of the events,

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which is a feature that business people, policymakers, and investors should consider in their application of this index.

Exhibit 6 compares the level of the KKT Index to realizations of recessions within various time spans. We are interested in analyzing periods when the probability of recession is rising. Therefore, we require that the standardized shift of the index – defined as its current level minus its average over the past year, divided by its standard deviation over the past year – is greater than 1.

Exhibit 6: KKT Index and Recession Realizations

| *Above threshold:* | *50%* | *60%* | *70%* | *80%* | *90%* | Unconditional Frequency |
|---|---|---|---|---|---|---|
| This month | 35% | 42% | 52% | 61% | 86% | 13% |
| Next 1m | 40% | 48% | 57% | 65% | 91% | 13% |
| Next 3m | 43% | 50% | 60% | 66% | 91% | 13% |
| **Next 6m** | **54%** | **61%** | **70%** | **77%** | **91%** | 17% |
| Next 12m | 68% | 74% | 83% | 86% | 91% | 24% |
| Next 18m | 75% | 78% | 84% | 86% | 91% | 30% |

We highlight the row corresponding to the realization of recessions over the subsequent six months for various levels of the index. We also report the unconditional frequency of recession for the various time spans. Exhibit 6 reveals that when the index exceeded 50%, 54% of the time a recession occurred within the next six months. When it exceeded 60%, a recession occurred 61% of the time within the next six months. When the index exceeded 70% the frequency of recessions was 70%. When it exceeded 80%, recessions occurred 77% of the




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time. And when it exceeded 90%, recessions followed 91% of the time. The correspondence between the index level and the incidence of recessions is remarkably strong; in fact, the correlation exceeds 99%, and the slope of the relationship equals one. By comparison, the unconditional likelihood of a recession within any six-month period is only 17%.

We next present the same analysis for the yield curve. Specifically, we show the incidence of recessions that occur over varying time spans once the yield curve becomes inverted and its one-year standardized shift is below -1.[6] And again we show the unconditional frequency of recession for these time spans.

Exhibit 7: Yield Curve and Recession Realizations

| *Below threshold:* | *0%* | Unconditional Frequency |
|---|---|---|
| This month | 12% | 13% |
| Next 1m | 14% | 13% |
| Next 3m | 18% | 13% |
| Next 6m | 29% | 17% |
| Next 12m | 46% | 24% |
| Next 18m | 73% | 30% |

Exhibit 7 shows the yield curve to be a much less reliable indicator of subsequent recessions than the KKT Index, especially for short horizons. It is only informative for a horizon of 18 months, and even for that horizon, it is less reliable than the KKT Index.




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## Summary

We apply the Mahalanobis distance to construct a new index of the business cycle. Specifically, we measure the statistical similarity of economic conditions each month to economic conditions that prevailed during prior periods of recession and robust growth. We then construct the index as the likelihood of recession relative to the likelihood of robust growth.

We argue that our index is more efficient than the Conference Board's indexes of leading, coincident, and lagging indicators because as a single index it conveys information about the path of the business cycle. We argue that, unlike the Conference Board Index of Coincident Indicators, our index gives an independent assessment of the state of the economy because it is constructed from variables that are different than those used by the NBER to identify recessions. We argue that our index is more objective than the NBER's identification of recessions because our index is strictly data driven and therefore, free of bias and persuasion. We argue that our index gives a more objective assessment of the business cycle than the Conference Board Indexes because it is expressed in units of statistical likelihood. And we argue that our index is more informative than the Conference Board indexes because it explicitly captures information about the co-movement of economic variables.

## Appendix 1: The NBER Methodology

The National Bureau of Economic Research's (NBER's) Business Cycle Dating Committee was created in 1978 (though the NBER has been publishing business cycle dates since 1929). It consists of eight (or so) members. On its website and in the most recent statement following a




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recession, released in September 2010,[7] the committee defines a recession as "a period of falling economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales." (As a side note, it is important to acknowledge that the four indicators, other than GDP, map very closely to the four indicators used in the Conference Board's Coincident Economic Index, which we review in Appendix 2.)

The September 2010 report also explains that: "The trough marks the end of the declining phase and the start of the rising phase of the business cycle. Economic activity is typically below normal in the early stages of an expansion, and it sometimes remains so well into the expansion." The NBER's website (https://www.nber.org/cycles/recessions.html, accessed December 2019) provides further detail:

> The NBER's Business Cycle Dating Committee maintains a chronology of the U.S. business cycle. The chronology comprises alternating dates of peaks and troughs in economic activity. A recession is a period between a peak and a trough, and an expansion is a period between a trough and a peak. During a recession, a significant decline in economic activity spreads across the economy and can last from a few months to more than a year. Similarly, during an expansion, economic activity rises substantially, spreads across the economy, and usually lasts for several years.
>
> In both recessions and expansions, brief reversals in economic activity may occur – a recession may include a short period of expansion followed by further decline; an expansion may include a short period of contraction followed by further growth. The Committee applies its judgment based on the above definitions of recessions and expansions and has no fixed rule to determine whether a contraction is only a short interruption of an expansion, or an expansion is only a short interruption of a contraction. The most recent example of such a judgment that was less than obvious was in 1980-1982, when the Committee determined that the contraction that began in 1981 was not a continuation of the one that began in 1980, but rather a separate full recession.




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> The Committee does not have a fixed definition of economic activity. It examines and compares the behavior of various measures of broad activity: real GDP measured on the product and income sides, economy-wide employment, and real income. The Committee also may consider indicators that do not cover the entire economy, such as real sales and the Federal Reserve's index of industrial production (IP). The Committee's use of these indicators in conjunction with the broad measures recognizes the issue of double-counting of sectors included in both those indicators and the broad measures. Still, a well-defined peak or trough in real sales or IP might help to determine the overall peak or trough dates, particularly if the economy-wide indicators are in conflict or do not have well-defined peaks or troughs.

### Appendix 2: Conference Board Methodology

The Conference Board publishes monthly business cycle Indicators, including composite indexes for leading, coincident, and lagging economic activity. Their Business Cycle Indicators Handbook describes the design and historical evolution of the indexes as follows:

> … In 1961, under the direction of Julius Shiskin at the Bureau of the Census, the U.S. Government began publication of a monthly report, Business Cycle Developments (BCD). This work was undertaken in cooperation with the NBER and the President's Council of Economic Advisers and made extensive use of time-series charts of NBER indicators (80 U.S. series and indexes of industrial production for seven major trading partners). In 1968, the report was renamed Business Conditions Digest, and in 1972 the indicators were shifted to another Commerce Department agency, the Bureau of Economic Analysis… (p. 9)
>
> … In 1995, the BEA […] transferred its program of research and production of business cycle indicators to The Conference Board… (p. 10)
>
> … Wesley C. Mitchell and Arthur F. Burns originated the indicator approach that made extensive use of business cycle indicators in the mid-1930s at the NBER… Over subsequent decades, the approach was developed and refined, mostly at the NBER under the leadership of Geoffrey H. Moore… (p. 13)
>
> … Clearly, the peaks and troughs in the coincident index line up closely with the official peak and trough dates from the NBER. The largest deviation is the three months at the 1960 peak. Eight of the last 13 turning points match exactly, and all




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> turning points in the coincident index correspond to either the beginning or end of a recession… (p. 14)
>
> *"Business Cycle Indicators Handbook." 2000. The Conference Board.*

The Conference Board's Dec 19, 2019 release of U.S. Business Cycle Indicators[8] explains that "The leading, coincident, and lagging economic indexes are essentially composite averages of several individual leading, coincident, or lagging indicators." Each input is weighted by a standardization factor which essentially normalizes for the standard deviation of that series. The standardization factors are scaled to sum to 1. The Coincident Economic Index includes four variables: (1) employees on nonagricultural payrolls, (2) personal income less transfer payments, (3) industrial production, and (4) manufacturing and trade sales. The Leading Economic Index comprises ten different variables, including stock prices and the interest rate spread on 10-year Treasury bonds versus the Federal Funds Rate, both of which correspond to variables we use in our index.

**Notes**

The material presented is for informational purposes only. The views expressed in the material are the views of the authors and are subject to change based on market and other conditions and factors; moreover, they do not necessarily represent the official views of Windham Capital Management, State Street Global Markets or State Street Corporation and its affiliates.




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[1] See Mahalanobis (1927) and Mahalanobis (1936).

[2] See Chow, Jacquier, Kritzman, and Lowry (1999).

[3] Industrial Production is the one-year percentage change in the monthly Industrial Production Index which is available from the Archival Federal Reserve Economic Data (ALFRED) repository maintained by the Federal Reserve Bank of Saint Louis starting in January 1920 (code: INDPRO). Prior to 1920 we use the Index of Industrial Production and Trade for the United States from ALFRED (code M1204BUSM363SNBR) as a proxy for Industrial Production. Nonfarm Payrolls is the rolling one-year percentage change in monthly Nonfarm Payrolls which is available from ALFRED starting in January 1940 (code: PAYEMS). Prior to 1940 we use the Index of Factory Payrolls for the state of New York from ALFRED (code M08G8AUS000NYM335NNBR) as a proxy for Nonfarm Payrolls. We scale down the standard deviation of the one-year changes in New York payrolls to adjust for the higher volatility of this series relative to nonfarm payrolls for the United States; the two series are 99% correlated during the period for which overlapping data is available. The return of the stock market is the rolling one-year price return of the S&P 500 Composite Index which is available monthly on Robert Shiller's website from 1871 to present. The slope of the yield curve is measured as the average difference between the ten-year U.S. treasury yield (code: USTRCN10) and the U.S. Federal Funds Rate (code: USFDFUND) over the preceding 12 months which is sourced from Datastream and captured on the 15th day of the prior month. Prior to November 1964, we use the difference between the ten-year U.S. Treasury yield and the annual risk-free rate, both available on Ken French's website, as a proxy for the yield curve. Prior to 1926 we use the difference between the ten-year U.S. Treasury yield (available on Robert Shiller's website) and the Federal Reserve Bank of New York discount rate (available on the NBER website) as a proxy for the yield curve. Finally, NBER recessions are identified by NBER and are available at a monthly frequency from ALFRED. For both Nonfarm Payrolls and Industrial Production data, we select all available vintages from ALFRED so we are able to identify the data that was actually available at each point in time, prior to any future revisions. Not all vintages are available prior to 1956, hence we treat the pre-1956 period as "in sample" to the extent that the data includes the benefit of subsequent revisions; our out-of-sample analysis begins in January 1956.

[4] We obtain data for the Conference Board's Coincident and Leading Indexes from the Archival Federal Reserve Economic Data (ALFRED), including prior vintages of point-in-time data where available. We plot the index values from the earliest vintage for which each month's observation is available.




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[5] In this event study, we use the NBER's designations of recessions. We define robust growth periods as quarters in which the trailing year's real GDP growth ranks near the top of its distribution over the prior ten years. We set a threshold of 85% to match roughly the historical frequency of recessions.

[6] Removing the requirement that the yield curve slope is falling (a standardized shift less than -1) does not materially change the results.

[7] "September 20, 2010 announcement of June 2009 business cycle trough/end of last recession," accessed December 2019 via www.nber.org/cycles/main.html.

[8] Accessed December 2019 via www.conference-board.org.




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