# Periods and structural breaks in US economic history 1959-2007

Robert McNown [1] and Knut Lehre Seip [2]

[1] Corresponding author:

International Affairs Program, Department of Economics, and Institute of Behavioral Science

University of Colorado

121 UCB, Boulder, CO 80309

Tel: 303-492-5996

Fax: 303-492-8960

Email: Robert.mcnown@colorado.edu

[2] Oslo University College, Department of Engineering

Pilestredet 35, POB 4 St. Olavsplass N-0130 Oslo, Norway

Tel: 47 22 45 32 10

Fax: 47 22 45 32 05

E-mail : Knut.Lehre.Seip@iu.hio.no

Key words: business cycles, economic history, inflation , unemployment, Phillips curve, composite leading indicator; composite lagging indicator; interest rate spread; federal funds; money supply; principal component analysis

## Periods and structural breaks in US economic history 1959-2007

*Abstract*

Principal component analysis (PCA) is applied to six macroeconomic time series observed over 1959-2007. Six periods in US economic history are identified by a cluster analysis of observations in the PCA score plot. The method is data-driven with no á priori information on the number or dates of breaks. Our findings give independent support to the effect of the oil price shock in 1973, and the introduction of the Great Moderation period. Of the 5 transition periods, two have been identified by previous studies as breaks (1973, 1984), one is a well-known date of monetary policy change (1979), and two had not previously been identified (1970, 1977-8). In the long run inflation and the federal funds rate are unrelated to industrial production and unemployment. Inflation and interest are positively associated as predicted by the Fisher hypothesis. These long run relations argue against the use of monetary policy to peg the rate of unemployment or real interest rates. In the short run inflation acts a leading indicator for unemployment for the period 1959 to 1997, but not for the period after 1997. The well-established reduction in macroeconomic volatility in the mid-1980s is specific to the period from 1985 to 1997; volatility subsequently rises above pre-1979 levels.

### *1. Introduction*

The US Economy has experienced several dramatic events and changes during the post- WWII period. Perhaps the most prominent of these changes is named “The Great Moderation” and started in the early 1980’s (1984Q1-3) and probably ended in 2007. (Canarella et al. 2009, McConnell and Perez-Quiros 2000). Other periods are related to the breakdown of the Bretton Woods exchange rate system around 1971 (Bayoumi and Eichengreen 1994), to the effect of the oil price shock in 1973Q1 (Perron 1989) and to changes in monetary policies around 1979, initiating the Volcker period of reserve targeting (Chowdhury and Schabert 2008, Sims and Zha 2006). To identify structural changes researchers have examined increases and declines in mean values and volatility for a range of macroeconomic variables, including GDP (McConnell and Perez-Quiros 2000, Kim and Nelson 1999) and prices (Stock et al. 2003), but also in generalized factors expressed by principal components (Stock and Watson 2007, Banerjee, Marcellino and Masten 2008). Results are, however, often not conclusive as suggested by expressions such as “...is the most plausible” (Stock and Watson (2003 p. 39) and “thinking of them as easily detectable regime shifts is mistake” (Sims and Zha (2006 p. 31)). Thus, there is a need for objective supporting information, using algorithm-based methods for event and period identification.

The present approach is an alternative to methods that address breaks in single time series and is related to studies using principal component analysis, e.g., Stock and Watson  (2007), Banerjee et al. (2008).  Cluster analysis is applied to the observations on the principal components to identify similarities between economic states. These clusters are the basis for identification of 4 out of 5 time windows that constitute transition events in the economy. We will return to the fifth transition below. With the exception of the selection of variables going into the analysis, and the choice of some threshold coefficients to be discussed later, the methods are data driven. There is no a priori assumption about the number or dates of breaks except that they are less than 10.

The periods identified depend upon the characteristics of six macroeconomic variables. We examine key variables such as industrial production, IP, the unemployment rate, and inflation. Movements in these target variables are often anticipated by changes in policy or indicator variables, including money supply, e.g., Sims and Zha (2006), the interest rate on federal funds, and the term structure of interest rates. These six variables provide the data for the analysis reported in this paper. For the present study we use static principal component analysis, a simple clustering algorithm, and run length theory as discussed below.

*Hypotheses*. Our first hypothesis is that it is possible to identify events or transitions in US macroeconomic history from 1959 to 2007 based on six major macroeconomic variables, without any a priori assumption on the number or timing of the transitions. Second, we hypothesize that these objectively identified transitions coincide with some events or breaks found in other studies, in some cases corresponding to known changes in macroeconomic policies. Third, we hypothesize that our PCA results can be related to known propositions in macroeconomic theory, such as the Fisher hypothesis and the Phillips curve, with direct implications for economic policy. Finally, we hypothesize that lead and lag features among the time series are consistent over subsets of the periods identified, but not for the whole period 1959-2007, strengthening the need for objective periodization of US economy.

This approach is complementary to structural break or macroeconomic switching studies, such as Perron (2008 p. 55) and (Stock and Watson 2007), in that transition dates are determined by the data. One major advantage of the procedures employed here is that the number of periods (equivalently, the number of breaks) is not predetermined, but is also determined empirically. The rest of the paper is organized as follows. We first present the data and the methods for this study in section 2. The methods are then applied to US economic time series observed from1959 to 2007 in section 3. Periods and transitions are identified and the characteristics of the periods are summarized with descriptive statistics. In section 4 we present the substantive economic and policy implications of the analysis, including the long run relations between the variables and the macroeconomic features of the periods and the transitions between them.

## 2. Data and Methods

For the identification of periods we choose three target economic time series: the inflation rate (in consumer prices, %), industrial production (Federal Reserve index) and unemployment (civilian unemployment rate, %) plus three policy instruments: the Federal Reserve 3-month interest rate (effective Federal Funds rate), the interest rate spread (10-year Treasury bond rate less the federal funds rate) and the money supply (M2, bil. $). Sims and Zha (2006) use a similar set of 6 economic time series to examine macroeconomic switching (commodity price index, M2, federal funds rate, GDP, consumer price index and unemployment rate) and Stock and Watson (2007) focus on a similar set: GDP, inflation, federal funds and spread between Treasury rates. All time series were obtained from Econmagic (2007).

### 2.1 Data treatment.

For the PCA study, we have used the entire period from 1959 to 2007 as a time window. The rationale is that we want to examine how relations among variables either persist, or change, between economic periods or “regimes.” Acceleration in output growth might be one such regime shifting factor. A policy implication of this issue of regime shifts was raised by the Chair of the Federal Reserve Board, “What if the technology revolution had, temporarily at least, increased the economy’s ability to expand? If that was the case, raising interest rates would be a mistake.” (Greenspan 2007). We chose not to de-trend the data by taking the first differences, since this method shifts peaks and troughs relative to the time axis, and introduces increased noise, Seip and McNown (2007 Appendix). For the PCA study we therefore first removed the long range trend by extracting the residuals from linear regressions of each time series against time.

### 2.2 The four methods

For this study we apply four methods that each approach the task of identifying periods in US economic history based mainly on data driven mechanisms. However, our choices of time series to be included and our de-trending methods, implicitly bring information on the type of events and relations we are considering, for example, on the interactions between policy variables and measures of business cycle activities.

*Method 1. Principal component analysis, PCA.* We first apply principal component analysis to the data with no leads or lags in the loading estimates (cf. Stock and Watson (2007). The PCA has six columns representing the six time series, and the rows are the monthly observations from 1959 to 2007. Two major plots are produced by PCA: the score plot, showing how the monthly observations are related, and the loading plot, which shows how the variables are related, e.g., Ergon (2009). Each time series is equally weighted since they are normalized by dividing by their standard deviations. PCA models are obtained by cross validation, employing the program Unscrambler © from CAMO (Trondheim, Norway). We examine plots made from the first two principal components that explain 58% and 22 %, respectively, of the variance in the data. This choice is supported by findings in two studies of 110 and 149 macroeconomic series that nearly all gains in forecasting come from use of only two components (Stock and Watson 2003, 2002, 2007).

Relations between variables can be read from the loading plot. Variables that have similar positions in the graph are closely positively related. Variables that are opposite to each other on a line through the origin are inversely related. When the variables are connected with lines to the origin, and the lines are perpendicular to each other, the variables are either unrelated or related through cyclic patterns (Seip and McNown 2007).

*Method 2 clustering analysis.* We examine clustering in the score plots produced by the PCA with the k-means clustering algorithm to define economic periods. This algorithm is a non-hierarchical clustering method that, given a certain numbers of clusters, k, iteratively assigns points to that cluster with the smallest Euclidian distance between that point and the cluster mean. Cluster means are then updated between iterations, Bow (1984) cited by Ryan et al. (1995). The PAST program was employed in this analysis (www.folk.uio.no/ohammer/past). To apply the k-clustering method the number of clusters, k, is specified with nine different choices (k = 2 to 10) assuming that 10 would be an upper limit for the number of periods from 1959 to present. We thus obtain nine sets of clusters, one for each of the nine choices of k.

In the following we define three types of time sequences: a *time window* is a sequence of months belonging to one cluster and not interrupted with more than two neighbouring "out-of- cluster" months (c.f., the 2- 3 month recession warning rule, (Filardo 1999)). A *transition* refers to the result of the k-clustering test with clusters k = 2, 10. It is found by aligning the result of the 9 clustering trials in time and calculating the cumulative number of shifts between neighbouring time windows over six months prior to, and six months after each month. A month when there are more than eight shifts between clusters (out of the nine cluster samples) is defined as being within a *transition episode.* The twelve months length corresponds with Filardo´s (1999) definition of a recession as a common movement in several variables lasting for 6 to 12 months. There was one exception: two transitions were less than a year apart, so we defined the two transitions and the period in-between as one transition. The historic *periods* are the time spans between two neighbouring transitions.

To give a simple example, assume that we run the clustering algorithm with k = 2 and k = 3 for a series of states corresponding to a sequence of 12 months.  Let the k = 2 clustering produce the sequence as the second row below. The months 1-4, 5-7 and 8-12 form three time windows in this series. (The switch counts will be explained below.)

| **Month** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **Switch count** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-clusters | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 2 |
| 3-clusters | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 2 |
| Cumulative trans. | | 0 | 0 | 2 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | | |
| Stochastic | 3 | 1 | 3 | 2 | 1 | 1 | 1 | 3 | 3 | 1 | 1 | 2 | 7 |

Let the 3-clustering algorithm on the same data give results as in the third row above. Here, the months 1-4; 5-9 and 10-12 form three time windows.  If we, for this example, define a transition as a period for which two or more sets exhibit cluster changes within the same three-month interval, then there is a common transition between the fourth and the fifth month, and the first four months will form a period. There are no more common transitions within an interval of three months in the two sets. The months five to twelve therefore also define a period.

In addition to the results from the k-clustering method we divide one period into two, based on the visual identification of differences in volatility of the time series (to be discussed further below). We know of no algorithmic clustering method that would allow us to do this.

We depict the resulting periods in the score plot by drawing rectangles around each period based on the coordinates of the observations' mean and standard deviation. Since the periods may contain observations that do not belong to the cluster that defines that period, we measure the *density* of states within each period. The density, D, is defined as the number of data points, n, within the time period, divided by the area these observations cover in the score plot:

$$D = \frac{n}{(PC1_{max} - PC1_{min}) \times (PC2_{max} - PC2_{min})}$$

where the suffixes min and max refer to $\underline{x} \pm x_{St.Dev.}$ PC1 and PC2 denote the coordinates of the first and second principal components. Greater density implies stronger similarity of the observations within a period, as measured by similar scores for the first two principle components.

Finally, we relate the clusters in the score plot to the location of variables in the loading plot to aid in the interpretation of the former. For example, if IP is in the upper left corner of the loading plot, then points toward the upper left corner of the score plot are associated with high values of IP. This allows us to characterize each cluster in terms of positions of the underlying variables.

*Method 3 - Sequentiality.* The PCA method and the clustering algorithm define “periods” in US economic history as a collection of monthly observations. The PCA is based solely on correlations between the individual observations and does not take into account the sequential nature of time series data. Therefore, a PCA plot could give rise to clusters that consist of temporally random observations from the whole time series on the one hand; or, at the other extreme, the clusters could consist of observations that are all sequential in time. We adopt a method from run length encoding theory to examine if the periods identified are significantly sequential (Wolfram 2008). With this method an array is constructed with all months, here 580, in one column that forms a time line and with a second column that gives the cluster assignment for each month. We then count the number of times the numbers in the second column change, that is, the switch count, S. For example, if the 5 periods all consist of uninterrupted sequences of months, the switch count would be S = 5 (note, a low S corresponds to a long run length). To evaluate the probability of obtaining sequential periods, we replaced the month numbers we found in each period with a stochastic number between 1 and 580 (the total number of months) and calculated the switch count for such periods. This lets us calculate the mean and standard error statistics that can be compared with the observed switch count. To give an example, the twelve months series above each have switch counts of 2. A stochastic assignment of the 12 months to 3 clusters could give a series like the one in the fifth row above which has a switch count of 7. A temporally random set of 12 observations has an average switch count of 6.6 with 95% confidence interval [6.1,7.1]. Therefore, the switch count in the first example is not the result of a random distribution of states among the 3 clusters. That is, sequences of observations tend to be contained within one cluster have similar economies.

We hypothesize that there is one cluster number that would give the optimum sequentiality. We define the optimum as the minimum ratio, R = S/k, between the measured switch count, S, and the number of clusters, k. However, since k = 1 and k = 580 both would give R = 1, we consider only an interior minimum to avoid these trivial selections.

*Method 4. Period characterization methods (Volatility and rotations).* For time series segments corresponding to the identified periods we calculate volatility for selected series and rotation in phase plots for pairs of series. Volatility is calculated from the standard deviation of the time series for unemployment and industrial production. The volatility of the pair is the product of the volatility of each. Since both time series are standardized to unit sample variance, the standard deviation is relative to 1.0. In addition, the dynamic relation between inflation and unemployment is captured by the rotational pattern in a phase diagram for these two variables, as seen in Philips curve representations, e.g., Dornbusch et al. (2008 p. 479).

### *3. Statistical Results*

We first present the results of the PCA and compare the distribution of points in the score and loading plots. We then present the results for transitions (9 to 26 months in length) and the periods (29 – 140 months in length) identified by the k-cluster algorithm. Finally, we draw some implications of the analysis for the relationships between inflation, unemployment and output across periods.
The score plot (Figure 1a) shows the time trajectories in a plane defined by the first principal component (explaining 58 % of the variance of the data set) and the second principal component (explaining 22 %). Some points in the score plot are numbered to aid in the interpretation of the periods. The five time periods labelled A through E were identified by the methodology described in the previous section.

----------------------------

Figure 1a and 1b in here

------------------------------

Period characteristics are summarized in Table 1, which also identifies each period in terms of overall macroeconomic activity and policy regime, the chair of the Federal Reserve Board, and shocks such as oil price changes. For each period the boundary dates defining the periods, the number of observation points, and the density of points within each period are shown in Table 1. The total area of the rectangles decreases from 58 PCA units to 12 units when the maximum and minimum values of the observations shown in Figure 1a are replaced by their mean values plus and minus one standard deviation. However, their shapes and positions are approximately retained (results not shown).

The rectangles defining the periods overlap because there are similar economic states during different time periods. For example, the overlap of rectangles A and E contains period A observations (from 1959 to 1970) and period E observations (from 1998 to 2007). Although each observation is classified as a member of only one period, it is not possible to disentangle visually the data in these overlapping rectangles.

A visual analysis suggests that the period D should be divided into two, D1 and D2, resulting in the six periods of Figure 1a. The most prominent characteristic distinguishing these two periods is their relative density, with observations in D1 showing considerably lower density (13; see Table 1) than those of D2 (99) or any other period. This difference is also related to the dramatic differences in volatility in inflation and output, as discussed below. The earlier of these two periods (1979 – 1985) was one of dramatic changes in inflation rates and output growth, initiated by the monetary contraction led by Fed Chairman Paul Volker, with its consequent recession and reduction of inflation through the early 1980s. The later period (D2), by contrast, is often identified as the onset of the Great Moderation, characterized by low inflation and steady output growth for most of this period.

----------------------------

Table 1 in here

-----------------------------

From the loading plot in Figure 1b it is seen that industrial production (IP) and unemployment (Un), as a general tendency, have an almost perfect inverse relationship to each other. Inflation, Inf, and the Federal Funds rate, FF, are not far from perpendicular to the line between IP and the unemployment rate, implying only a weak relation between Inf and FF and the two other variables in the long run. The money supply variable and the interest rate spread are inversely related to each other and also almost perpendicular to the IP-Un line. These characterizations of the underlying variables in the loadings plot are interpreted further in the discussion below.The time trajectories in the score plot predominantly slant from the lower left corner to the upper right corner, corresponding to a movement from low inflation and Federal funds rate (and high money supply) to high inflation and high interest rates.

*Significance of the periods.* The statistical significance of our period identification is measured by the switch count, S. For k = 5 the switch count achieved a value of 44, meaning the cluster assignments for the sequence of 580 months changed value 44 times. If all months had been distributed randomly into the 5 periods, the number of switches would have been 293 ± 6 (n = 10; 1% confidence interval). Thus, the sequential nature of the observations within the periods is highly significant. The ratio, R = S/k, defining our criterion for the optimal number of clusters, achieves a (interior) minimum for k = 5 (Figure 2a).

----------------------------

Figure 2 in here

------------------------------

Plotting annual data for unemployment versus inflation for the five first periods A to D2 (1959- 1997), a circular pattern emerges as in Figure 2c. The trajectories rotate largely clockwise (71% clockwise and 29% counter-clockwise rotations, average clockwise angle = - $58^{O}$; average counter-clockwise angle = $16^{O}$, n = 37). (Rotations are calculated as in Seip and McNown 2007.) However, for the last time window, E (1998 to 2007), there are 63% counter-clockwise rotations and 37% clockwise rotations, (clockwise and counter-clockwise angles about equal). The rotational pattern in Figure 2c can be compared to the visually clockwise rotations shown in (DRI 1990) and quoted by Dornbusch et al. (2008 p. 479) for the period 1961 to 1988. Interpretations of these rotational features are presented in the discussion of Section 4.3.

*Volatility in output and inflation*. Examining the differing spreads of the slanted trajectories in Figure 1a, it appears that there are marked changes in the volatility of inflation across periods. The movements are almost parallel to the direction between origin and the point representing inflation (Figures 1a and 1b), so that the standard deviation of these movements corresponds to volatility in inflation. To verify this interpretation, the standard deviations of output, IP, and inflation, Inf, for each of the periods are shown in Figure 2b. These points show that volatility in both output and inflation was low in the years 1959 - 1979 (periods A-C). However, the volatility for both increased dramatically over the years 1979 - 1985 (period D1), then decreased, in particular for inflation, in 1985 - 1997 (period D2), but increased again for both from 1999 to the present (period E). Volatility in output in periods D2 and E never returns to its low levels of the early years 1959-1979.

## 4 Discussion and Policy Implications

We first discuss the historic periods and thereafter movements in the economy over long and short time spans. Policy implications are drawn from the analysis, building upon related literature.

### *4.1 Historic time windows.*

The statistical results show that modern US economic history can be organized into five or six relatively well defined time periods. This meets the first objective of the analysis: a data driven approach, the PCA method combined with the k-clustering algorithm, divides US economic history into well-defined periods of nearly sequential observations. The five period division is supported by two findings: The first is that we identified four consistent transition periods in the PCA score plot. The second is that by dividing into five clusters, the number of times the sequence of observations moves from one cluster to another is minimized relative to the number of clusters.

The division of cluster D into two pieces does not follow from the clustering algorithm, but is also empirically based. Periods D1 and D2 are sharply distinguished by differing densities (13 for D1 vs. 99 for D2, see Table 1), and this division is reinforced by the differences in volatility shown in figure 2b. The six periods identified empirically correspond to recognizable episodes in macroeconomic policy and fluctuations:

*Period A* (1959:1-1970:1) encompasses the low-inflation expansion of the Kennedy-Johnson administrations. Although often associated with expansionary fiscal policy, the early 1960’s also featured high money supply growth, consistent with the placement of this period towards the left of the score plot (Figure 1a).

*Period B* (1970:10-1973:2) is an era of considerable macroeconomic turmoil featuring the abandonment of the Bretton Woods fixed exchange rate system. The points in the score plot for period B correspond to higher inflation rates but lower industrial production levels than those of period A.

*Transition period B to C* (1973:3-1975:5) is the longest transition period in the study, far exceeding the others in length (26 vs. 9-12 months). It features erratic monetary policy and the first oil price shock in 1973:8. Perron (1989), and Perron and Wada (2006) designate 1973 as structural break point for GNP, in the sense that the growth rate slowed persistently following the break. The transition period also includes the stagflation of 1973-74.

*Period C* (1975:6-1978:5) features a sharp recession in 1975. It shows a lower density and a moderately higher volatility than the two prior periods. Chowdhury and Schabert (2008) find that during these three periods, spanning the years 1960-1979 in their analysis, the monetary authorities accommodated inflationary tendencies through expansion of non-borrowed reserves, and they contend that macroeconomic volatility was consequently higher before 1979 compared to the period after 1982. Figure 2b presents contradictory evidence, with both output and inflation volatility considerably lower during the first three periods than in the later three. However, the PCA-clustering algorithm reinforces Chowdhury and Schabert's designation of early 1979 as a policy break point, with the onset of reserve targeting associated with a broader shift in the macroeconomy as characterized by the six variables of this study.

Figure 1a shows a steady rightward shift along the PC1 axis as the economy moves from period A to B and then to period C. Observing how higher values of PC1 are associated with higher levels of inflation and unemployment (figure 1b), the progression through these three periods represents the well-known rise of stagflation associated with the late 1970s.

*Period D1* (1979:10-1985:3) began with the second oil price shock, but with a contractive monetary response initiated by Paul Volker. The resulting recession broke the back of inflation, with the points in the D1 section of the score plot moving from the top right (high interest rates and inflation) to the lower right half (low inflation, high unemployment, and low industrial production). Recovery, with a reduction in unemployment and increased output after 1982 following the Kemp-Roth tax cuts, is represented by the movement in the score plot back towards the zero level on the horizontal axis.

The transition between periods D1 and D2 at 1985:5 is based both on the clustering of points, and on a visual detection of a change in density at approximately that same time, Figure 1a. Since several authors find 1984 as a break point year (summary in Stock et al.(2003) and Stock and Watson (2007)), we examined if that year would give a better visual clustering. However, dividing the data at 1984 caused a higher degree of overlap between the two clusters. The period 1984-1985 could probably be defined as a transition period between the periods D1 and D2, but we do not adopt that convention here. We know of no clustering technique that would allow identification of a transition based both on clustering and a time line that incorporates differences in volatility.

*Period D2* (1985:5-1997:2) shows a continued recovery with only moderate inflation. This was an era of sustained moderate economic growth with a mild recession in the early 1990's. This period is positioned slightly below the center in the score plot, indicating moderate values of the monetary variable and the two interest rate measures, and slightly below average inflation and industrial production. This period is in approximately the same position in the PC space as period C, indicating roughly similar policy stances and economic outcomes. The years from 1985 through 1996 suggest desirable policy outcomes only in comparison to the economic challenges faced by the Volker Fed (period D1). In other words, the Great Moderation is only moderately great in terms of overall economic performance, and only in comparison to the more difficult policy environment of combating inflation during the previous period.

P*eriod E* (1998:5-2007:4) contains the shocks of 9-11, the wars in Afghanistan and Iraq, the housing price bubble, and sustained increases in petroleum and other commodity prices. Monetary policy was strongly expansionary as indicated by the location of this cluster at the left side of the score plot (low federal funds rate, low spread, and high values of the money supply). This was a period of low inflation and moderately strong levels of industrial production. Part of this period, 2004 to 2007, is called the "conundrum" by Alan Greenspan (2007 p. 377). With reference to Figure 1a, the date 2001M7 appears to almost qualify as a transition period. It is two months before 9/11 2001, the suicide attacks upon the United States by al-Qaeda. The event, or the near-transition, in July 2001, that occurred two months *before* "nine-eleven" is marked with a bold circle in Figure 1a and appears to initiate an increase in volatility after that time. It may be related to the IT bubble that broke during the end of 2000 (Soros 2008).

A number of studies have identified the mid-1980s as the onset of a marked reduction in macroeconomic volatility (Kim and Nelson 1999; McConnell and Perez-Quiros 2000). Some authors credit the less accommodating stance of monetary policy with the reduced volatility in inflation and output (Adam 2009; Clarida , et al. 2000). In particular, a policy of inflation targeting consistent with the Taylor rule is found to reduce inflation and therefore uncertainty about future prices. Reduced price uncertainty, in turn, enables firms to minimize pricing errors in both input and output markets, resulting in a closer match between private output decisions and the objectives of policy makers (Adam 2009).

The reduction in inflation and output volatility around 1985 is clearly confirmed by Figure 2b, showing the sharp decrease especially in inflation volatility between periods D1 and D2. However, volatility in output during period D2 still remains well above that of periods A, B, and C, and inflation volatility rises again in period E to levels that exceed the earlier periods (1959 – 1978). Again, the performance of macroeconomic policy during the Great Moderation stands out favourably only in comparison to the difficult years of the Volker Fed. Furthermore, the rise in volatility between periods D2 and E presages the chaos of the Great Recession, which lies beyond the endpoint of our sample (May 2007).

The present study identifies 5 breaks for the period 1959-2007. It provides independent support to the macroeconomic impact of the oil price shock in 1973, and to the identification of the Great Moderation period (beginning in 1984, but here in 1985). The end of our 78M5-79M6 transition has to our knowledge not been identified by others as a structural break, but is identified as a "well-established" shift in monetary policy, as well as supported by empirical evidence on money supply response to changes in expected inflation (Chowdhury and Schabert 2008). We also identify two transitions: 70M1-70M10 and 97M2-98M5 that to our knowledge have not been established as transitions or breaks before. Thus, we found support for our second hypothesis; three of our transition periods coincide with events identified in other studies.

### *4.2 Long-run movements and macroeconomic relations*

Figure 1b shows that industrial production and unemployment move in opposite directions from each other, with IP in the upper left corner and unemployment in the lower right. This confirms standard views of the behaviour of these to variables over the business cycle. The location of both inflation and the rate of interest in the upper right quadrant is consistent with the Fisher hypothesis. Inflation and the rate of interest are almost orthogonal to IP and unemployment, and are therefore either unrelated or related cyclically and out of phase to these real variables. Both interpretations are consistent with the absence of a direct trade-off between inflation and unemployment. Therefore, the PCA provides empirical support for several theoretical propositions in macroeconomics supporting our third hypothesis. However, a primary tenet of the quantity theory of money is not supported by the PCA: monetary expansions are not associated with inflation. In the loadings plot (1b) inflation and money lie in opposite quadrants. Financial innovation has undermined monetary aggregates as reliable indicators of monetary policy, and therefore unlinked the fundamental money-price level relation of the quantity theory. Furthermore, money and output (and the unemployment rate) are orthogonal to each other, so that the monetary aggregate fails as an indicator for future levels of real economic activity.

Support for the Fisher hypothesis reinforces Friedman 's (1968) scepticism about the ability of policy makers to peg the rate of interest. As he pointed out an initial monetary expansion could temporarily drive down nominal interest rates, but the resulting macroeconomic expansion would increase the demand for loanable funds, causing a subsequent rise in interest rates. Previous investigations of the Fisher hypothesis have produced only mixed support (cf. Rapach and Weber 2004 for a review of this evidence). Our methodology allows the relation between inflation and interest rates to emerge as a long run phenomenon, abstracting from short run fluctuations that can obscure this fundamental connection.

### *4.3 Trans-period movements: Inflation, unemployment and output*

Examining the phase diagram for annual observations on inflation and unemployment, we see that it rotates largely clockwise for the years 1959-1997 (Periods A-D2), Figure 2c. This finding is consistent with the interpretation of this relation as a Phillips spiral, characteristic of the dynamic adjustment around a natural rate of unemployment. Given a short run downward-sloping Phillips curve, an expansionary monetary policy induces a rise in wage and price inflation, and a subsequent reduction in unemployment – a movement upwards and to the left in Figure 2c. As inflation is incorporated into real wage expectations, unemployment rises as the Phillips curve shifts out to the right, defining a new short run trade-off between inflation and unemployment. At this point a policy contraction lowers inflation and increases unemployment, moving downwards and to the right in Figure 2c. These adjustments in inflation and unemployment describe the clockwise movement that is apparent in that figure.

This rotational pattern, together with the long run orthogonality between inflation and unemployment (figure 1b), captures Friedman's (1968) second observation about the limits of monetary policy. An expansionary policy may induce a temporary reduction in unemployment below its natural rate, as described in the previous paragraph. However, as expectations catch up with the reality of wage and price inflation, the economy will move back towards its long run equilibrium level of unemployment as determined by structural labor market factors. Friedman's unifying principle of limits on policy, supported by the current analysis, is that monetary policy should not attempt to peg real variables (the unemployment rate or the real rate of interest). Instead, monetary authorities should target nominal factors, such as the rate of inflation, consistent with contemporary strategies of modern central banking.

The clock-wise rotation of the trajectories in the unemployment (x-axis) inflation (y-axis) phase diagram indicates that inflation acts as a leading index for unemployment. The rotational pattern suggests that there are periods, like the period from 1973 to 1974 and from 1978 to 1980, when both inflation and unemployment are high and increasing during episodes of stagflation.

It is interesting that the clockwise rotational pattern appears not to hold for the last period, E, from 1998 to 2007. During this period the U.S. economy was buffeted by real and financial shocks (the attack of the World Trade Center, the wars in Afghanistan and Iraq, steep increases in oil prices, the stock market crash) while low cost imports maintained downward pressure on prices. This combination of real shocks tempered by checks on inflation may account for the reversal of the inflation – unemployment spiral after 1998. Both inflation and unemployment became unhinged from the conduct of monetary policy during this period, with exogenous real shocks impacting the labor market and foreign competition enforcing price discipline. Consequently, the mechanism described previously relating short run changes in inflation and unemployment around the natural rate no longer holds for this period.

## 5 Conclusion

In this study several data-based methods are employed to divide recent U.S. macroeconomic history into well-defined periods. Two principal components are extracted from six macroeconomic time series that reflect the main features of business activity over the years 1959 to 2007. The time series observations (score plot) on these two principal components provide a summary of business cycle activity over this 49 year period. Cluster analysis is applied to these factor scores to classify observations into groups with similar characteristics as captured by the two principal components. This cluster analysis is successful in defining five distinct periods, preserving with considerable regularity the sequential nature of the data, despite the fact that no information on temporal ordering is employed in defining the clusters. One of these five periods is divided into two segments based on the sharply differing volatilities of the observations over these two sub-periods. With the exception of the choice of the six variables going into the analysis, the definition of the periods from the PCA and cluster analysis is entirely data driven. In comparison with other methods for identifying regime changes, such as the Markov switching model, the PCA-clustering procedure has the advantage of not requiring a predetermined number of periods.  Of the 5 transition periods, two have been identified by previous studies as breaks (1973, 1984), one is a well-known date of monetary policy change (1979), and two had not previously been identified (1970, 1977-8).

The loadings plot from the PCA also reproduces two standard propositions in macroeconomic theory, both reinforcing a fundamental rule of policy. Inflation and interest rates move together as suggested by the Fisher hypothesis; inflation and unemployment are orthogonal to each other, consistent with the natural rate of unemployment concept. The support for these hypotheses presented here bolsters Friedman’s (1968) lessons on the inability of monetary policy to influence real variables in the long run. In addition, annual data on inflation and unemployment in a phase plot follow a Phillips curve spiral, consistent with the hypothesis of short run inflation-unemployment trade-offs circling around a fixed natural rate of unemployment. This consistency with fundamental macroeconomic propositions provides additional validation of the data-based procedures for period identification employed in this study.

Further new findings emerge from this study. First, the well-established reduction in macroeconomic volatility in the mid-1980s is seen to be specific to the period from 1985 to 1997. Volatility in both inflation and output subsequently rises above levels experienced prior to 1979. In this sense the Great Moderation, sometimes attributed to a stable monetary policy of inflation targeting, is not remarkable in comparison to previous post-World War II periods. Second, the dynamic relation between inflation and unemployment changed fundamentally after 1997. With the real economy buffeted by major shocks and inflation kept in check by low cost foreign competition, the linkages between inflation and unemployment no longer adhere to the clockwise pattern of the short run Phillips curve. These observations only become apparent as a result of the objective period identification achieved by the PCA-clustering algorithms.

*Literature*


Adam, K. (2009) Monetary policy and aggregate volatility. *Journal of Monetary Economics,* 56**,** S1-S18.

Banerjee, A., M. Marcellino & I. x. x. x. Masten. 2008. Forecasting macroeconomic variables using diffusion indexes in short samples with structural change. In *Frontiers of economic globalization,* eds. D. Rapach & M. Wohar. Elsevier.

Bayoumi, T. & B. Eichengreen (1994) Macroeconomic Adjustment Under Bretton Woods and the Post-Breton-Woods Float: An Impulse-Response Analysis *The economic journal,* 104**,** 813-827.

Bow, S.-T. 1984. *Pattern recognition*. New York: Marcel Dekker.

Canarella, G., W. S. Fang, S. M. Miller & S. K. Pollard. 2009. Is the great moderation ending? UK and US evidence. In *California state university, Los Angeles* Los Angeles.

Chowdhury, I. & A. Schabert (2008) Federal reserve policy viewed through a money supply lens. *Journal of monetary economics* 55**,** 825-834.

Clarida, R., J. Gali & M. Gertler (2000) Monetary policy rules and macroeconomic stability: Evidence and some theory. *Quarterly Journal of Economics,* 115**,** 147-180.

Dornbusch, R., S. Fischer & R. Stratz. 2008. *Macroeconomics (10 edition)*. Boston: McGraw Hill.

DRI. 1990. *Data Resources*. Data Resources Inc, McGraw-Hill.

Econmagic. 2007. Index of lagging indicators 1959M1-2003M4. Econmagic.

Ergon, R. (2009) Informative score-loading-contribution plots for multi-response process monitoring *Chemometrics and Intelligent Laboratory systems,* 95**,** 31-34.

Filardo, A. J. (1999) How reliable are recession prediction models? *Federal reserve bank of Kansas city economic review* 84**,** 35-49.

Friedman, M. (1968) ROLE OF MONETARY POLICY. *American Economic Review,* 58**,** 1-17.

Greenspan, A. 2007. *The age of turbulence. Adventures in a new world.* . New York: The Penguin press.

Kim, C. & C. Nelson (1999) Has the US economy become more stable? A Bayesian approach based on a Markov-switching model of the business cycle *REVIEW OF ECONOMICS AND STATISTICS,* 81**,** 608-616.

McConnell, M. M. & G. Perez-Quiros (2000) Output fluctuations in the United States: What has changed since the early 1980`s? *The American Economic Review,* 90.

Perron, P. (1989) The great crash, the oil price shock, and the unit root hypothesis. *Econometrica,* 57**,** 1361-1401.

---. 2008. Dealing with structural breaks. In *Palgrave Handbook of Econometrics, Vol. 1: Econometric Theory,* eds. T. C. Mills & K. Patterson. Palgrave Mcmillan.

Perron, P. & T. Wada. 2006. Let´s take a break: trendes and cycles in US real GDP. Boston: Boston University.

Rapach, D. E. & C. E. Weber (2004) Are real interest rates really nonstationary? New evidence from tests with good size and power. *Journal of Macroeconomics,* 26**,** 409-430.

Ryan, P. D., D. A. T. Harper & J. S. Whalley. 1995. *PALSTAT, Statistics for paleontologists*. Chapman and Hall.

Seip, K. L. & R. McNown (2007) The timing and accuracy of leading and lagging business cycle indicators: a new approach. *Intenational journal of forecasting,* 22**,** 277-287.

Sims, C. A. & T. Zha (2006) Were there regime switches in US monetary policy? *American Economic Review,* 96**,** 54-81.

Soros, G. 2008. *The new paradigm for financial markets : the credit crisis of 2008 and what it means*. London: PublicAffairs.
Stock, J. & M. Watson. 2007. Forecasting in Dynamic Factor Models Subject to Structural Instability. Department of economics, Harward University.
Stock, J. H. & M. W. Watson (2002) Forecasting using principal components from a large number of predictors. *Journal of the American Statistical Association,* 97**,** 1167-1179.
---. 2003. Has the business cycle changed? evidence and explanation. In *Federal reserve bank of Kansas city symposium: Monetary policy and uncertainty*. Jacson Hole, Wyoming.
Stock, J. H., M. W. Watson, J. Gali & R. E. Hall. 2003. Has the business cycle changed and why? In *Macroeconomics Annual 2002*, 159-+.
Wolfram, S. 2002. A New Kind of Science. Champaign, IL: Wolfram Media.

**Table 1 Economic periods defined by PCA clustering of six time series during the period 1959 to 2007. The series are 1. Industrial production, 2. Inflation rate, 3. Unemployment; 4. Federal funds rate, 5 Spread defined as 10 year bond minus 3 - month Federal funds rate, 6. Money supply, M2. n = number of months within each period. D is the density of states within a unit area of the PCA score plot in Figure 1.**

| Cluster | Period, number of months(n), density(D) | Characteristics in terms of six parameter values | Period characterization. |
|---|---|---|---|
| | | | |
| A | 59:1-70:1; n = 132; D = 64 | High money supply, medium industrial production, low inflation | Kennedy-Johnson expansion; Martin |
| B | 70:10- 73:2; n = 29; D = 53 | High inflation, medium to high industrial production | Oil price shocks; end of fixed exchange rates; unstable money growth; Burns |
| C | 75:6-78:5; n = 36; D = 41 | Stagflation | Burns, Miller |
| D1 | 79:2-85:4; n = 75; D = 13 | Moving from high inflation and high federal funds rate to high unemployment. Monetary contraction. Industrial production low. | Restrictive monetary policy. Kemp-Roth Tax cut 1981; Paul Volcker (79-87). Rising oil prices to 1981. |
| D2 | 85:5-97:2<br>n = 142; D=99 | Moderate industrial production, and money supply; low inflation | "The great moderation period." Volcker, Alan Greenspan (87-05), Iraq invades Kuwait August 1990; Peak oil price > $30/barrel |
| E | 98:5 – 07:4<br>n = 97, D = 50 | High money supply, high industrial production, low/medium unemployment; low interest rates. | Alan Greenspan (87-05)<br>Ben S. Bernanke (05-); shock of 9/11; aggressively low federal funds rate; steadily increasing oil prices $10-60/barrel |

Figure 1a. Principal component score plot of the time series (1959-2007): Industrial production, Inflation, Unemployment; Federal funds rate, Interest rate spread, and Money supply (M2). Rectangles show boundaries of the PC1 and PC2 coordinates for observations within each period. The letters identify the periods as defined by two dates that bracket the periods. The thick circle designates the date July 2001.

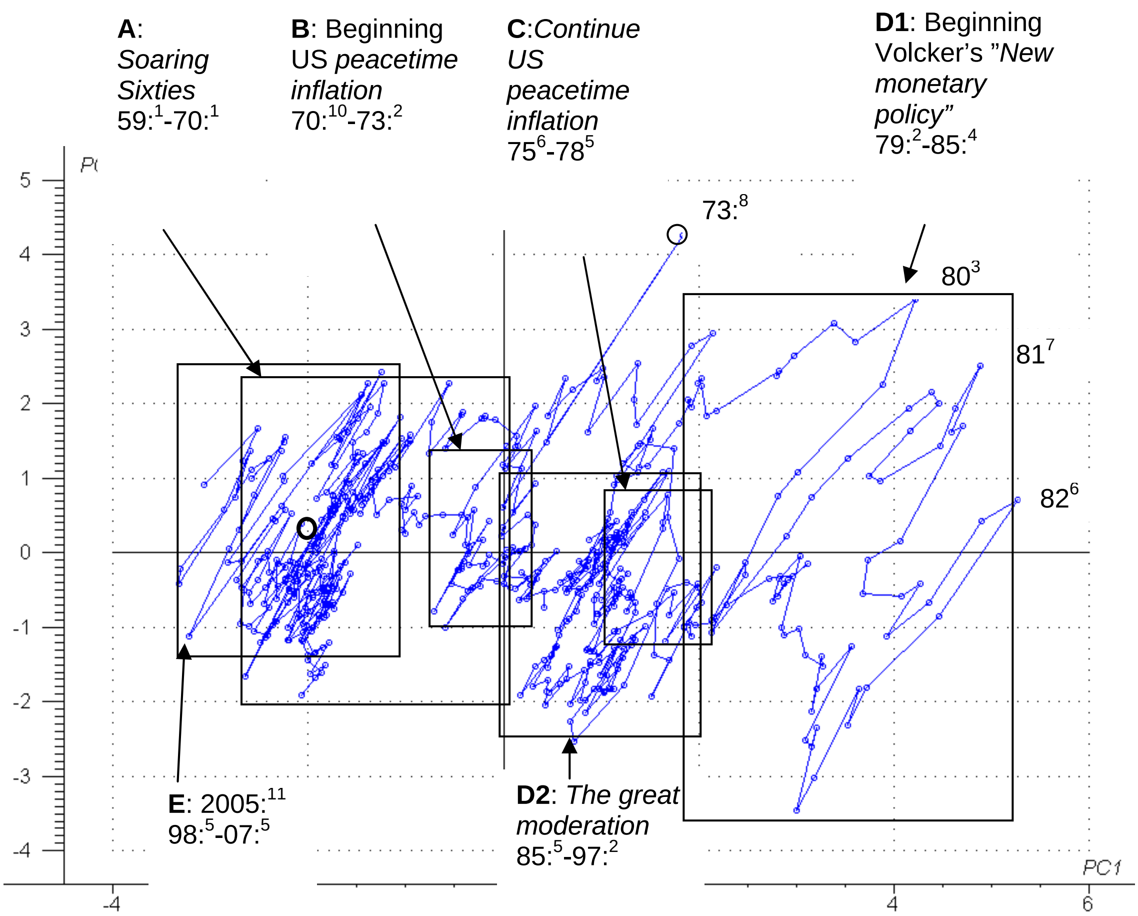


Figure 1b. Principal component loadings plot of the six time series (1959-2007): Industrial production (IP), Inflation, Unemployment, Federal funds rate, Spread, and Money supply.

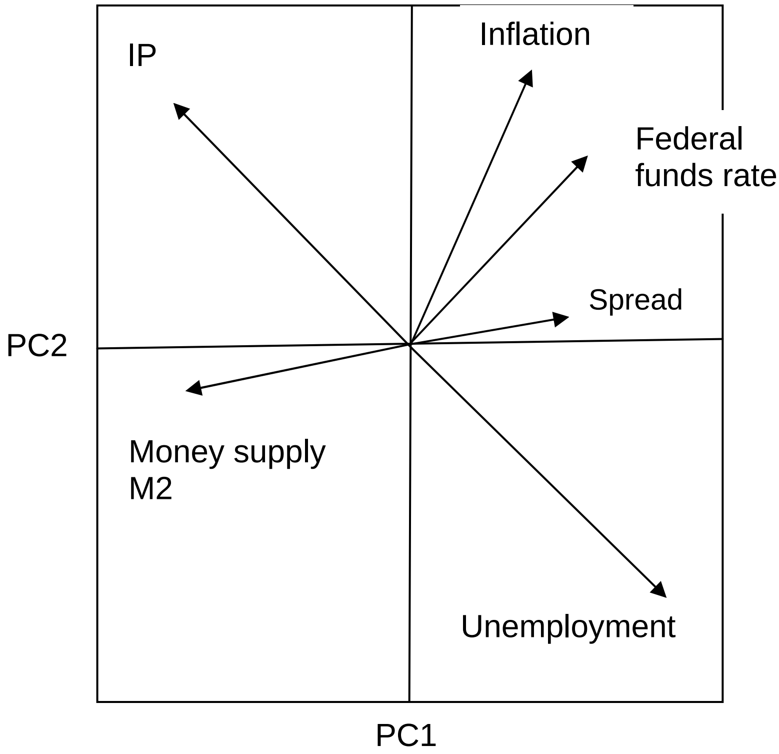
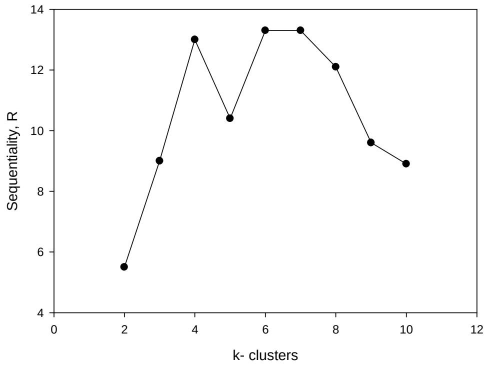
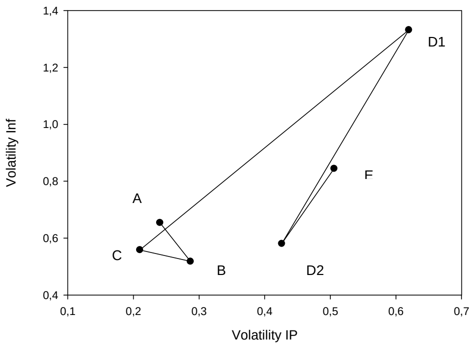


Figure 2. Sequentiality within periods, volatility, and inflation vs. unemployment. (a) Sequentiality of observations in the score plot, Figure 1a; sequentiality index measures the number of times that months in the time series 1959- 2007 change clusters relative to the number of clusters (k) in the k-clustering algorithm. (b) Volatility in output versus volatility in inflation. (c) Phase plot for unemployment vs. inflation.

(a)




(b)




(c)