Inflation and Changing Expenditure Shares

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Inflation is an index of price changes for many goods. As such, the behavior of inflation is determined by the behavior of (1) price changes for individual goods, as well as (2) the weights that the index puts on the price changes of different goods. Most macroeconomic analyses of the time-series behavior of inflation—whether empirical or theoretical—implicitly emphasize the former determinant of inflation.[1] Theoretical analyses tend to focus on one-sector models in which there are no weights to shift, and empirical analyses tend to focus on the univariate properties of some broad inflation rate.

If rates of price change did not differ much across goods, then shifts in the weights would not matter much for inflation. In fact, there has been substantial variation in price change behavior across goods, and the weights on two of the three broad categories in consumption price indexes have shifted dramatically over the last 50 years (Figure 1). Those facts motivate us to investigate the importance of changing weights for three fundamental time-series properties of inflation: level, volatility, and persistence. The extent to which shifting weights are important for these properties may have implications for macroeconomic modeling. Suppose that inflation was highly persistent but that all of the persistence was accounted for by long-term shifts in the weights in the inflation measure. We might then conclude that in one-sector macroeconomic models, high inflation persistence is not a desirable feature.

We propose and implement two approaches to measuring the contribution of changing expenditure shares to inflation behavior. Both involve constructing an alternative inflation measure that holds fixed the weights on price

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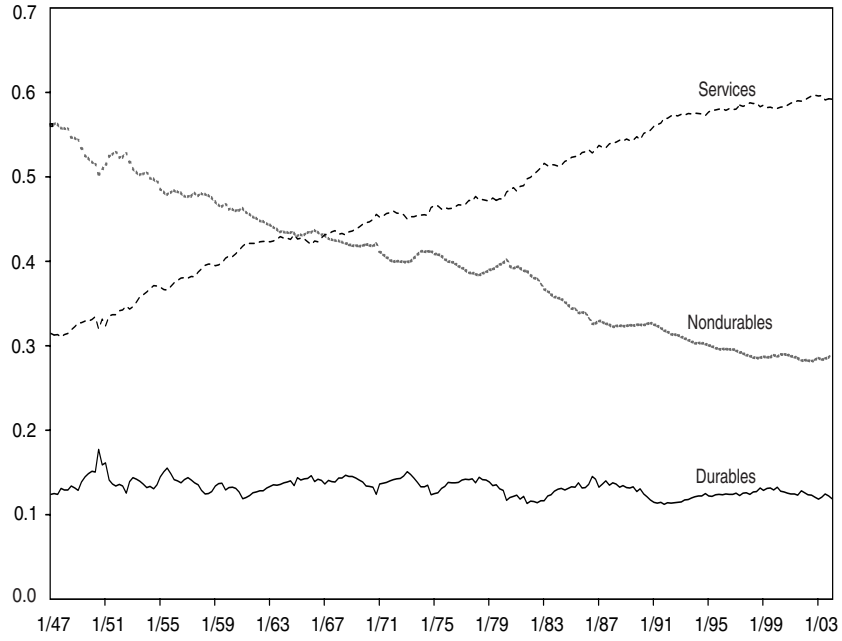
[1] Wolman (1999) is an example of an article that fits this description.

Figure 1 Sectoral Expenditure Shares



changes for different goods. We describe the behavior of the level, volatility, and persistence of the alternative inflation measures. The role of changing expenditure shares is then revealed by the divergence between the behavior of actual inflation and the fixed-weight measures. Neither approach leads to a dramatic revision in our understanding of post-war U.S. inflation; that is, the broad features of inflation over the past 50 years cannot be accounted for by changing expenditure shares. However, in more subtle ways, changing expenditure shares have been important for the behavior of inflation. For example, we attribute 15 basis points of quarterly inflation, on average, to changing expenditure shares over the period from 1947 to 2004. Expenditures have shifted to services, and the relative price of services has risen persistently over the last 50 years. This shift toward services has tended to make the overall inflation rate higher, other things equal. The caveat "other things equal" is important. Expenditure share shifts have been one factor influencing the behavior of inflation, but monetary policy has had the ability to counteract the effect of shifting expenditure shares on inflation. Thus, one could reinterpret the statement above as "in order to achieve the inflation behavior we have observed, monetary policy has had to counteract a 15-basis-point upward effect on inflation coming from the long-run shift in expenditures toward services."

It is important to make clear at the outset that we are not arguing that one should measure inflation by holding fixed the weights on different goods. It is well known that good price indexes from the standpoint of economic theory ought to have time-varying weights that reflect time-varying expenditure patterns. Our concern is instead one of fact-finding: Given the existence of changes in expenditure shares, to what extent can those changes account for the behavior of inflation? To answer this question, we construct alternative fixed-weight price indexes.

For the most part, recent literature on inflation in the United States has abstracted from the heterogeneity that underlies overall inflation. Notable exceptions are Clark (2003) and Bauer, Haltom, and Peterman (2004). Bauer, Haltom, and Peterman focus on the behavior of core inflation over the last 20 years. They decompose core inflation into contributions of different goods and services. These contributions are the product of expenditure shares and individual price changes. Bauer, Haltom, and Peterman find that just two components, rent and used vehicles, account for much of the decline in consumer price index (CPI) inflation over this period. Clark's emphasis is on inflation persistence, which we will discuss further. He contrasts the behavior of inflation persistence over time to the behavior of the persistence of disaggregated price changes. He finds that the persistence of disaggregated price changes tends to be lower than the persistence of inflation. Our article differs in its explicit emphasis on changing expenditure shares over time. Clark's findings, though, suggest that expenditure share behavior may be an important determinant of inflation persistence.

1. INFLATION IN THE UNITED STATES

The variables we are concerned with are all produced by the Bureau of Economic Analysis of the United States Department of Commerce. They are the price index for personal consumption expenditure; the subindexes for durable goods, nondurable goods, and services; and the expenditure shares for durable goods, nondurable goods, and services. Before turning to the behavior of these variables, it is useful to provide some background on price indexes, and, in particular, on the price index for personal consumption expenditure. (Henceforth, we will refer to this index as the PCE price index, and to its rate of change as PCE inflation.)

PCE inflation data are constructed from underlying price and quantity data for a large number of categories of goods and services. In turn, the price data for those underlying categories are constructed from more direct observation of prices on an even larger number of specific items (i.e., goods and services). The latter construction is performed mainly by the Department of Labor's Bureau of Labor Statistics. For the most part, the same item prices that form the basis for PCE inflation also form the basis for the more widely known CPI

inflation, which is produced by the Bureau of Labor Statistics. We focus here on PCE inflation for two reasons. First, the methodology used to produce the PCE inflation numbers corresponds more closely to notions of price indexes suggested by economic theory. Second, the PCE methodology makes it more straightforward to decompose inflation in a way that isolates the effect of changing expenditure shares.

The formula used to create the PCE inflation rate is known as a Fisher ideal index. We will first provide the formula and then interpret it.[2] We define π_t to be the PCE inflation rate in quarter t, $x_{i,t}$ to be the period t dollar expenditures on category i, and $\pi_{i,t}$ to be the rate of price change for category i from period $t-1$ to period t. The PCE inflation rate is

$$\pi_t = \sqrt{\left[\sum_{i=1}^{I} \omega_{i,t-1}\pi_{i,t}\right]\left[\sum_{i=1}^{I} \theta_{i,t}\pi_{i,t}\right]}, \tag{1}$$

where

$$\omega_{i,t} \equiv \frac{x_{i,t}}{\sum_{j=1}^{I} x_{j,t}}, \text{ and}$$

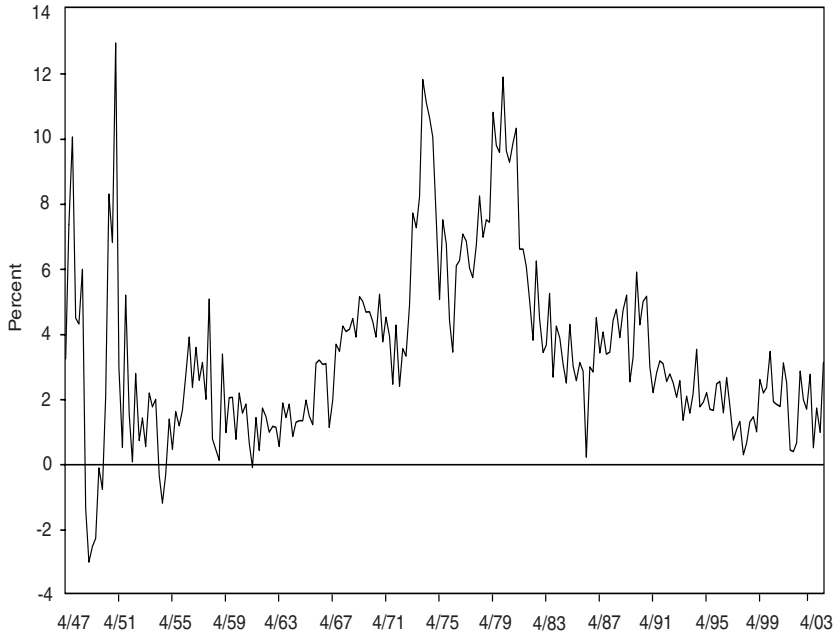
$$\theta_{i,t} \equiv \frac{x_{i,t}/\pi_{i,t}}{\sum_{j=1}^{I}\left(x_{j,t}/\pi_{j,t}\right)}, \text{ .for } i = 1, ..., I.$$

Both objects in square brackets in (1) are weighted averages of the rates of price change for each good and service. The weights, $\omega_{i,t-1}$, are simply the expenditure shares for category i in period $t-1$; thus, the first weighted average, $\sum_{i=1}^{I} \omega_{i,t-1}\pi_{i,t}$, measures the rate of price change for the basket of goods purchased in period $t-1$. The weights, $\theta_{i,t}$, are the hypothetical expenditure shares that are derived by combining period t real quantities with period $t-1$ prices. Thus, the second weighted average, $\sum_{i=1}^{I} \theta_{i,t}\pi_{i,t}$, measures the rate of price change in period t for the basket of goods purchased in period t. Finally, PCE inflation (π_t) is the geometric average of these two inflation rates.

It is clear from (1) that changes in expenditure shares on different goods and services are incorporated in the behavior of the PCE. In contrast, the CPI is a fixed-weight index; changes in expenditure shares are incorporated in the CPI only every two years. The precise way in which changing expenditure shares are incorporated in PCE inflation is somewhat complicated, as seen in (1). Fortunately, for our purposes, the true PCE inflation rate is well approximated by a simpler formula that aggregates prices for the three major spending categories using what is known as a Divisia index. The Divisia approximation

[2] See Webb (2004) and Clark (1999) for more detailed discussions of how the PCE price index is constructed.

Figure 2 PCE Inflation



to the PCE which we will use is

$$\pi_t^D = \sum_{i=N,D,S} \omega_{i,t-1}\pi_{i,t}, \tag{2}$$

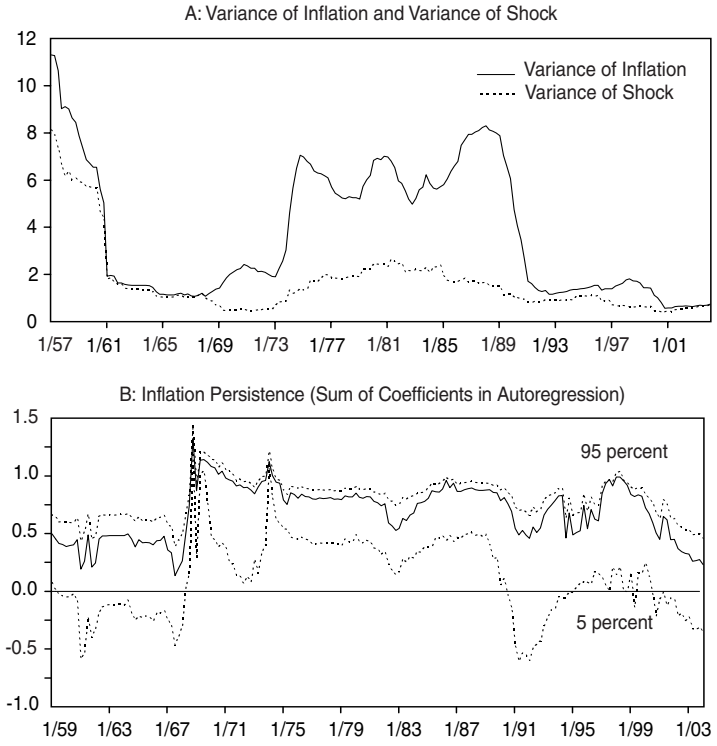
that is, the expenditure-share-weighted average of price changes for nondurable goods, durable goods, and services. This approximation is convenient because it allows us to easily decompose the behavior of inflation into the part accounted for by changing expenditure shares and the part accounted for by changing rates of price change for the main spending categories.

The Level of Inflation

Figure 2 displays the quarterly PCE inflation rate from 1947 to 2004, expressed in annualized percentage terms.[3] This figure displays the major facts about inflation in the United States. Inflation was highly volatile immediately after World War II, then declined and became more stable during the 1950s. In the

[3] In all figures, the month and year on the x-axis indicate the first month of the quarter represented by the tick mark.

Figure 3 Volatility and Persistence



mid-1960s, inflation began a steady rise that continued for the rest of the decade. The 1970s were characterized by high and volatile inflation, and then in the early 1980s inflation declined dramatically. Over the last 15 to 20 years, inflation has been low and stable, apart from a moderate increase in the late 1980s. The average PCE inflation rate from 1947 to the present has been 3.42 percent. Though these basic facts are clear, much about the behavior of the level of U.S. inflation remains in dispute. For example, economists agree that the Federal Reserve can determine the average level of inflation over periods of several years. Thus, there is consensus that the Federal Reserve could have brought about a much lower average inflation rate in the 1970s. However, there is no consensus about why the Fed behaved as it did. We direct interested readers to Hetzel (1998), Orphanides (2003), and Cogley and Sargent (2003) for an introduction to the vast literature analyzing that question.

Inflation Volatility

Panel A of Figure 3 displays two measures of inflation volatility. The first, the solid line, is the variance of inflation, measured over ten-year rolling windows ending at the date on the horizontal axis. For example, the entry labeled "4/79" is the sample variance of inflation from the third quarter of 1969 through the second quarter of 1979.

Variance is the most natural way to measure volatility. However, variance can be a misleading measure of volatility if a time series is serially correlated. For example, consider the first-order autoregressive process,

$$y_t = \rho y_{t-1} + \varepsilon_t, \tag{3}$$

where ε_t is an i.i.d. normal random variable with mean zero and variance v. The variance of y_t is $\text{var}(y) = \left(1 - \rho^2\right)^{-1} v$. Thus, even though v is the only source of random volatility in y, the autoregressive coefficient ρ contributes to the variance of y.

The effect of serial correlation (that is, persistence) on variance leads us to present a second measure of volatility along with variance. The dashed line is the variance of the residual in an autoregressive representation of inflation, where the autoregression is estimated by OLS, and the lag length is chosen by the Akaike information criterion (AIC). This residual variance can be thought of as a measure of the volatility that remains after taking out predictable variation in the series during the particular ten-year window. For both measures, volatility fell dramatically until 1961, then remained low until the early 1970s. It rose in the 1970s, fell in the 1980s, and has been historically low over the last five years. The fact that the variance of inflation rose much more than the shock variance from the late 1960s through the late 1980s suggests that there were changes in the serial correlation properties of inflation over this period. We consider these next.

Inflation Persistence

"Inflation persistence" refers to the degree to which a sudden change in the inflation rate tends to persist over time. As we just saw, persistence leads to higher variance, other things equal. In recent years much research has been devoted to estimating the persistence of inflation in the United States. This literature was spawned by Fuhrer and Moore (1995), who argued that inflation in the United States was characterized by high persistence and that models with forward-looking pricing behavior were unable to replicate the observed level of persistence. Fundamentally, however, interest in inflation persistence dates back to Lucas (1972) and Sargent (1971). These authors showed that the accuracy of econometric procedures for estimating Phillips curve slopes could be sensitive to the univariate persistence properties of inflation. Recent research on inflation persistence has, like Fuhrer and Moore, been concerned

with quantifying the degree of inflation persistence and then assessing whether and to what degree observed persistence is an inherent structural feature or an artifact of the particular monetary policy in place. The extent to which inflation persistence is structural has important implications for the consequences of alternative monetary policies.[4]

There are several ways to measure inflation persistence. Pivetta and Reis (2004) discuss the different measures in detail. In the case of the first-order autoregression discussed above, the different measures of persistence are all equivalent, and persistence is summarized by the parameter, ρ. For more complicated processes, the different measures can give different rankings of persistence. We will follow Levin and Piger (2003) and Clark (2003) in measuring inflation persistence by the sum of autoregressive coefficients in a univariate autoregressive representation of inflation.[5] If the sum of autoregressive coefficients is ρ, then $1/(1-\rho)$ represents the long-run effect of a permanent unit shock to the autoregression. That is, if in each period from $t = 0$ to ∞, the autoregression in (3) is hit by $\varepsilon_t = 1$, and $\varepsilon_t = 0$ for $t < 0$, then at $t = \infty$, we have $y_t = 1/(1-\rho)$.

Panel B of Figure 3 displays ten-year rolling-window estimates of PCE inflation persistence from the second quarter of 1959 to the first quarter of 2004. For each quarter, we take the ten years of prior data and estimate an autoregression for inflation, using the AIC to select lag length. The sum of autoregressive coefficients is then plotted in this panel, along with centered 90 percent confidence intervals constructed by semiparametric bootstrapping.[6]

Persistence fluctuates between 0.16 and 1.20 over the full sample. It was low until the late 1960s, then jumped up in late 1968 and early 1969, and remained high (roughly 0.8 or above) until 1999, apart from a brief period in 1983 and some rapid fluctuations between 1991 and 1995. In the last five years, our persistence measure has declined steadily, reaching 0.23 in the first quarter of 2004. The confidence intervals are quite wide. However, they encompass zero a much greater percentage of the time than they encompass unity, shedding some doubt on the conventional wisdom that inflation is inherently highly persistent.[7] The increase in inflation persistence in the late 1970s corresponds to the divergence (panel A of Figure 3) between the variance of inflation and the variance of the shock to the inflation autoregression. It is

[4] Different degrees of structural inflation persistence correspond to different degrees of price rigidity or other nominal frictions. Different specifications of nominal frictions, in turn, correspond to different real implications of changing policy rules.

[5] In the first-order example, the sum of coefficients is simply ρ.

[6] To generate the confidence intervals for a given quarter, we simulated 5000 samples by combining the estimated autoregressive coefficients with resampled residuals. These confidence intervals should be interpreted with caution; Hansen's (1999) grid bootstrap method deals more effectively with the bias associated with persistence being close to unity.

[7] This statement requires the caveat that the confidence intervals will be misleading when persistence is near unity.

not as easy to reconcile the joint behavior of these three objects later in the sample when the variance of inflation drops sharply. That is, the sharp drop in the variance of inflation without a sharp drop in the shock variance is not explained by a sharp drop in inflation persistence. Such a discrepancy can occur because, for autoregressions with more than one lag, the relationship between variance of the series and variance of the shock depends on the individual autoregressive coefficients, not just their sum.

2. SECTORAL INFLATION AND OVERALL INFLATION

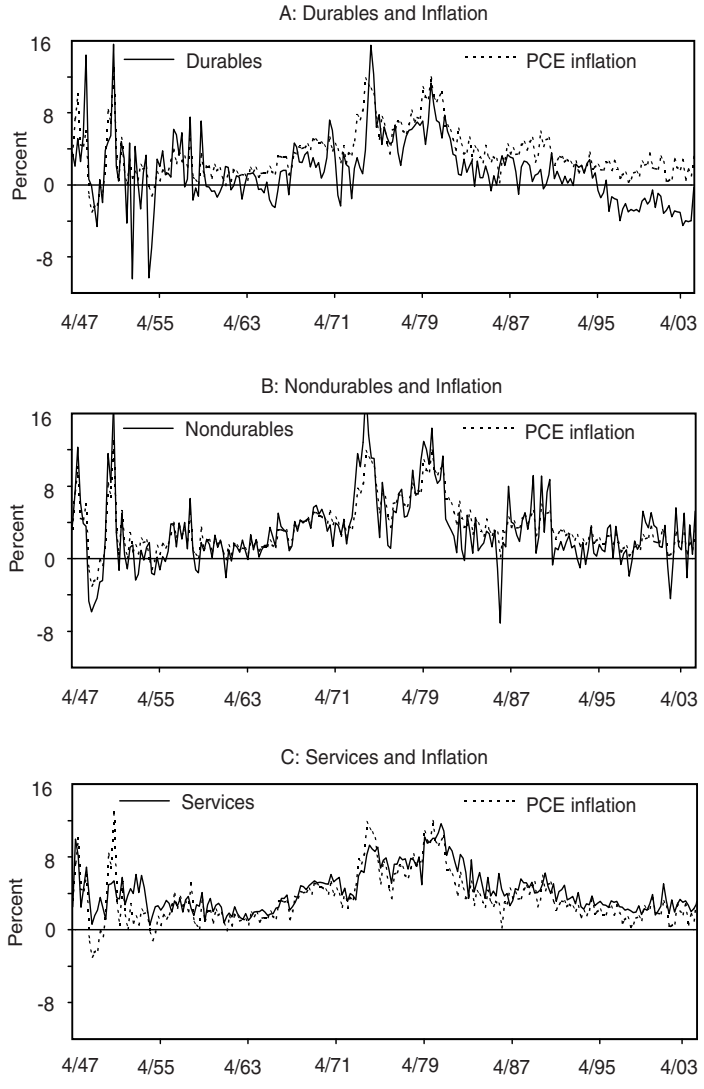
Having laid out the basic features of inflation behavior in the United States, we now turn to the components of inflation, expenditure shares, and price changes for the three consumer spending categories of durable goods, nondurable goods, and services. In this section we document the behavior of expenditure shares and price changes. The changes in expenditure shares over time and the variation in rates of price change across sectors then motivate our attempts in the next section to quantify the contribution of changing expenditure shares to the behavior of overall inflation.

Figure 1 plots expenditure shares for durable goods, nondurable goods, and services from 1947 to the present. Whereas the expenditure share for durable goods has fluctuated narrowly, between 12 and 18 percent, the shares of nondurables and services have respectively risen and fallen dramatically. In January 1947 services accounted for only 31 percent, and nondurable goods accounted for 56 percent of personal consumption expenditure. In January 2004, services accounted for 59 percent, and nondurable goods only 29 percent of personal consumption expenditure.

Figure 4 plots rates of price change for the three first-level components of personal consumption expenditure, together with the overall PCE inflation rate. Each series differs somewhat from overall inflation. Services price changes have generally been above PCE inflation, averaging 4.22 percent, compared to 3.42 percent for overall inflation. Durables price changes have generally been below PCE inflation, averaging 1.59 percent. The main distinguishing feature of nondurables price changes—which have averaged 3.09 percent—is that they have been more volatile than PCE inflation. This feature is reflected in Figure 5, which plots rolling-window variances of the sectoral rates of price change.[8] Figure 6 shows that the differences in rates of price

[8] Volatility of price changes of nondurables will not be a surprise to readers familiar with the concept of core PCE inflation. Core PCE inflation excludes food and energy prices, which are notoriously volatile and comprise a large share of nondurables expenditures. For short-run monetary policy purposes, core PCE inflation is generally preferred to overall PCE inflation.

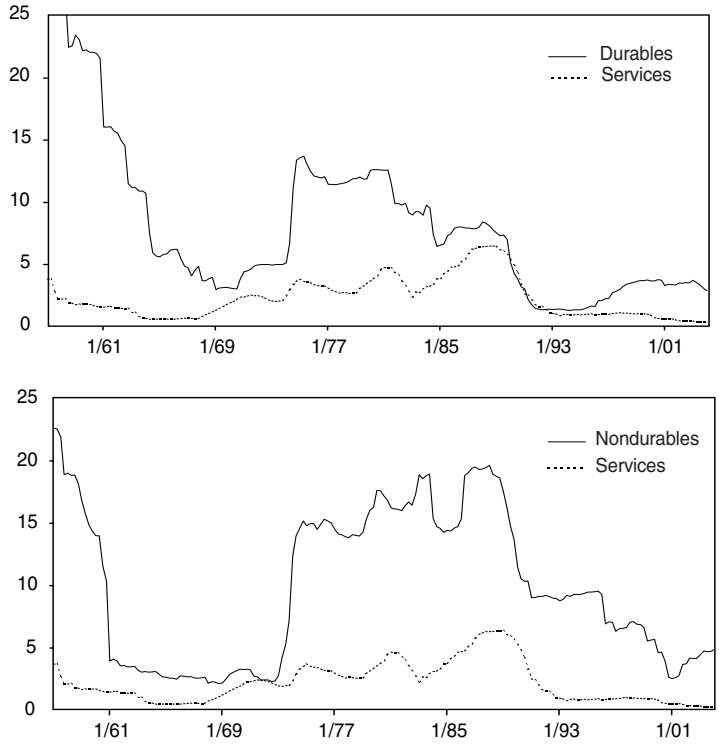
Figure 4 Sectoral Price Changes



change across sectors have cumulated significantly over time: the price index for services rose by a factor of eleven since 1947, whereas the price index for durables rose by less than a factor of three. In the last eight years, the price index for durable goods has actually been falling.

Figure 7 plots persistence for rates of price change of durables, nondurables, and services. The persistence measure is, again, the sum of auto-

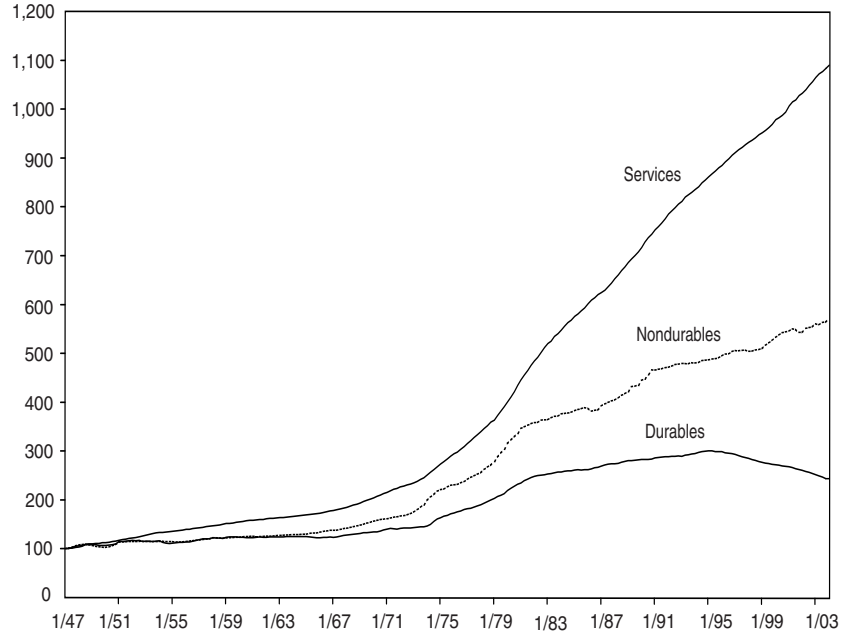
Figure 5 Variance of Sectoral Price Changes



regressive coefficients. The persistence measure moves broadly together across sectors, with services usually being the most persistent. Early in the sample, nondurables price changes are more persistent than durables price changes, but this ordering is reversed after about 1980. At the end of the sample, when persistence of PCE inflation is declining, the same is happening to rates of price change for services and nondurables, but persistence rises dramatically for durables price changes in 1998 and stays high until the present.

Together with the large swing in expenditure shares, differential behavior of price changes across sectors suggests that expenditure share changes may have been important contributors to the behavior of inflation. We will estimate this contribution in the next section. However, even if we find little contribution, the existence of expenditure shifts together with differing rates of price change across sectors is an important observation. Sectoral shifts and heterogeneous price behavior across sectors may have implications for

Figure 6 Sectoral Price Levels



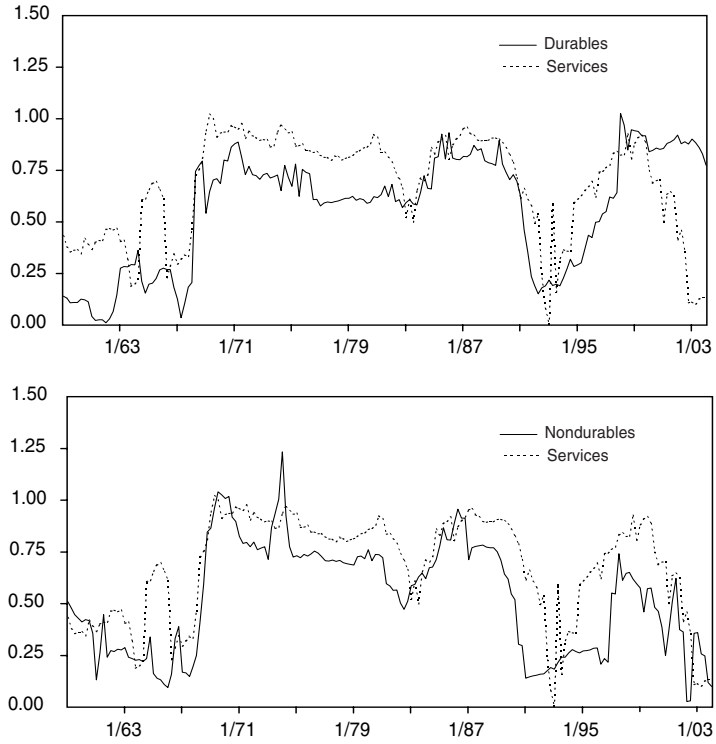
monetary policy. For example, the nature of optimal monetary policy may be sensitive to these factors.[9]

3. REINTERPRETING CHANGES IN THE BEHAVIOR OF INFLATION

To assess the importance of changing expenditure shares for the behavior of inflation, we construct two series that control for long-run shifts in expenditure shares. The first series we call "1947 inflation," and we create it by replacing the actual expenditure shares, $\omega_{i,t-1}$, in (2) with expenditure shares that fluctuate only transitorily around their 1947:4 levels. We generate 1947 inflation in two steps. First we estimate quadratic time trends for the expenditure shares under the restriction that the trends sum to one. Then we create a series of synthetic weights (expenditure shares) for each date in our sample by adding the 1947:4 value of the trend weight to the difference between the actual weight

[9] Aoki (2001), Erceg and Levin (2002), and Huang and Liu (2003) study cyclical fluctuations and monetary policy in multi-sector models. Wolman (2004) considers the optimal steady state inflation rate when there are relative price trends across sectors.

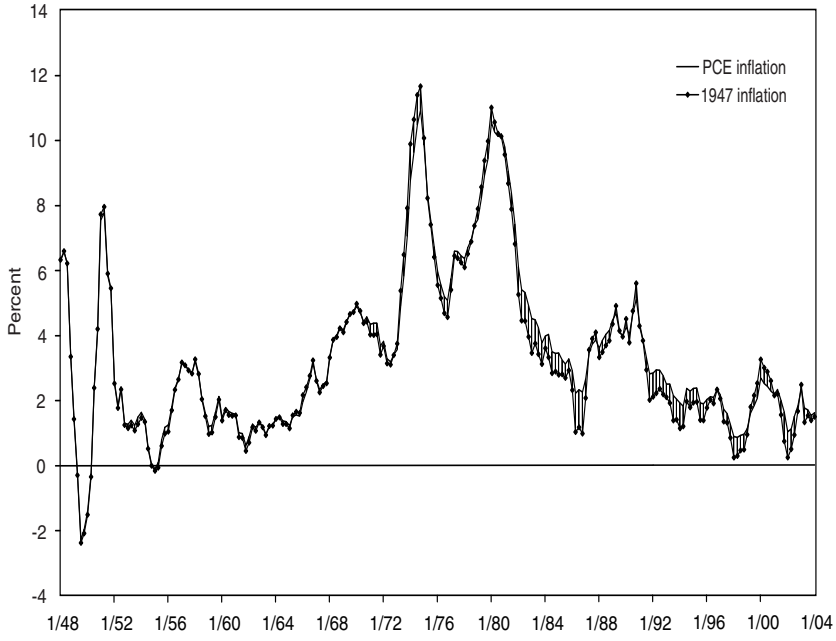
Figure 7 Persistence of Sectoral Price Changes



at each date and the trend weight estimated for that date. The initial values for the trend weights are 0.12 for durables, 0.31 for services, and 0.56 for nondurables. We allow for fluctuations around the trends because these may be independent of the long-run sectoral shifts we want to control for.

Our second approach to controlling for changing expenditure shares involves extracting the first principal component of the three sectoral rates of price change. The principal component is a weighted average of the three sectoral rates of price change, with the weights being chosen in order to maximize the variance of the weighted average. The weights are 0.76 for services, 0.21 for durables, and 0.03 for nondurables. The principal component can be viewed as the common component of the sectoral rates of price change. Because actual expenditure shares are not used to compute the principal component, they do not directly influence this series. Kapetanios (2002) suggests a similar measure as reflecting a notion of core inflation. The weighted median inflation measure emphasized by Bryan and Cecchetti (1994) is similar

Figure 8 1947 and PCE Inflation



in spirit to the first principal component in that it attempts to cut down the contribution of noisy components of inflation.[10]

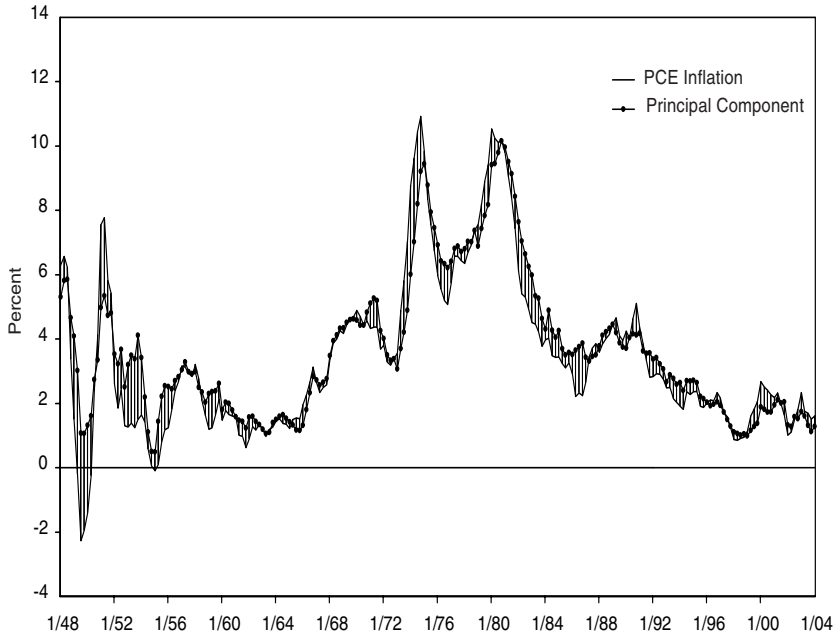
The Level of Inflation

Figure 8 displays the time series for 1947 inflation, and Figure 9 displays the first principal component of sectoral inflation. In each case we plot annual averages of the series and display them along with the corresponding series for actual PCE inflation. Both series share the broad patterns that characterize actual PCE inflation. If someone familiar with postwar U.S. inflation were shown either panel, it might not be difficult to convince them that it was a plot of actual inflation. However, there are some differences between both series and actual PCE inflation.

In the case of 1947 inflation, it is not surprising that these differences arise in the latter part of the sample, when the actual weights are quite different from the 1947 weights (services having risen and nondurables having fallen). Because nondurables inflation is more volatile than services inflation, the

[10] As a measure of core inflation, Bryan and Cecchetti (1994) use the weighted median of 36 components of the all-urban consumers CPI. This is the "central point, as implied by the CPI expenditure weights, in the cross-sectional histogram of inflation each month" (p. 203).

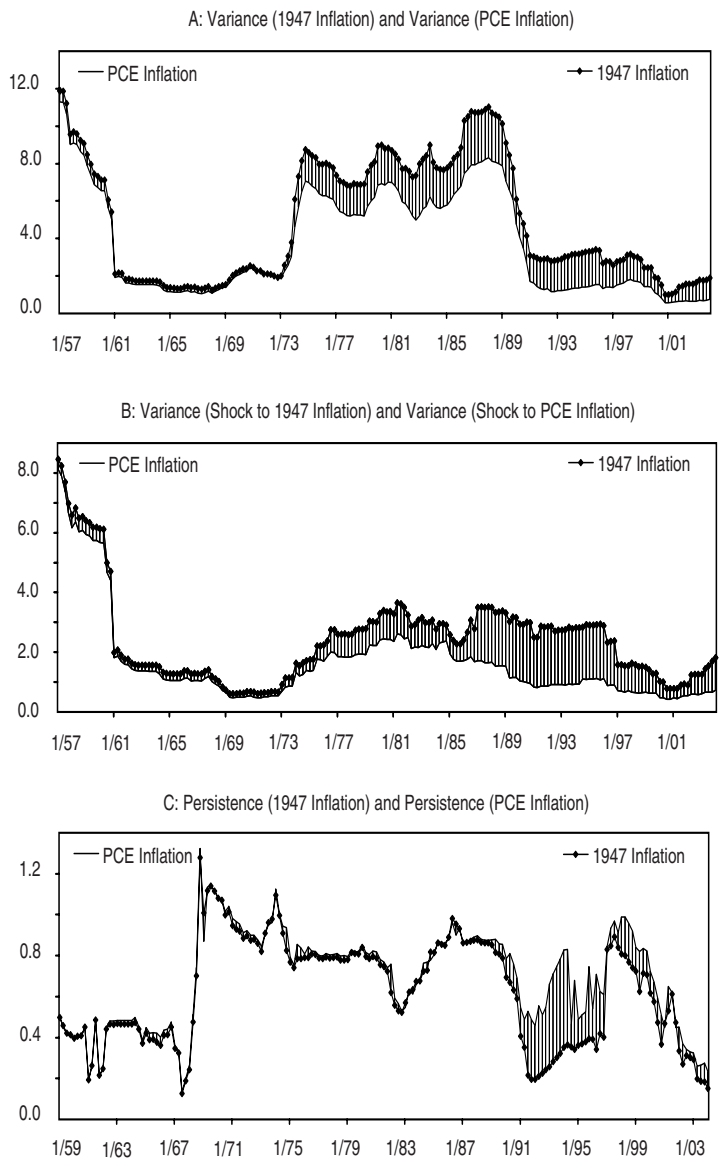
Figure 9 Principal Component and PCE Inflation



1947 inflation series with its higher weight on nondurables is noticeably more volatile than actual inflation in the last 20 years of the sample. In addition, because the average rate of price change for nondurables has been lower than that for services, 1947 inflation has a somewhat lower average level, 3.27 percent versus 3.42 percent. The lower level is obscured, however, by the higher volatility.

The principal component of sectoral price changes has a higher average than PCE inflation, at 3.64 percent. This is attributable to the high weight the principal component places on services. The high weight on services and low weight on volatile nondurables explains the fact that the principal component is less volatile than either PCE inflation or 1947 inflation. A notable feature of the principal component's behavior is that, unlike actual inflation and 1947 inflation, it is quite stable between 1983 and 1991. The other two series exhibit a sharp fall around 1986 and then a sharp rise followed by an additional steady increase. Referring to the sectoral price changes in Figure 4, we can understand this divergence as reflecting the fact that the volatility in the mid-to-late 1980s is largely accounted for by volatility in nondurables price changes.

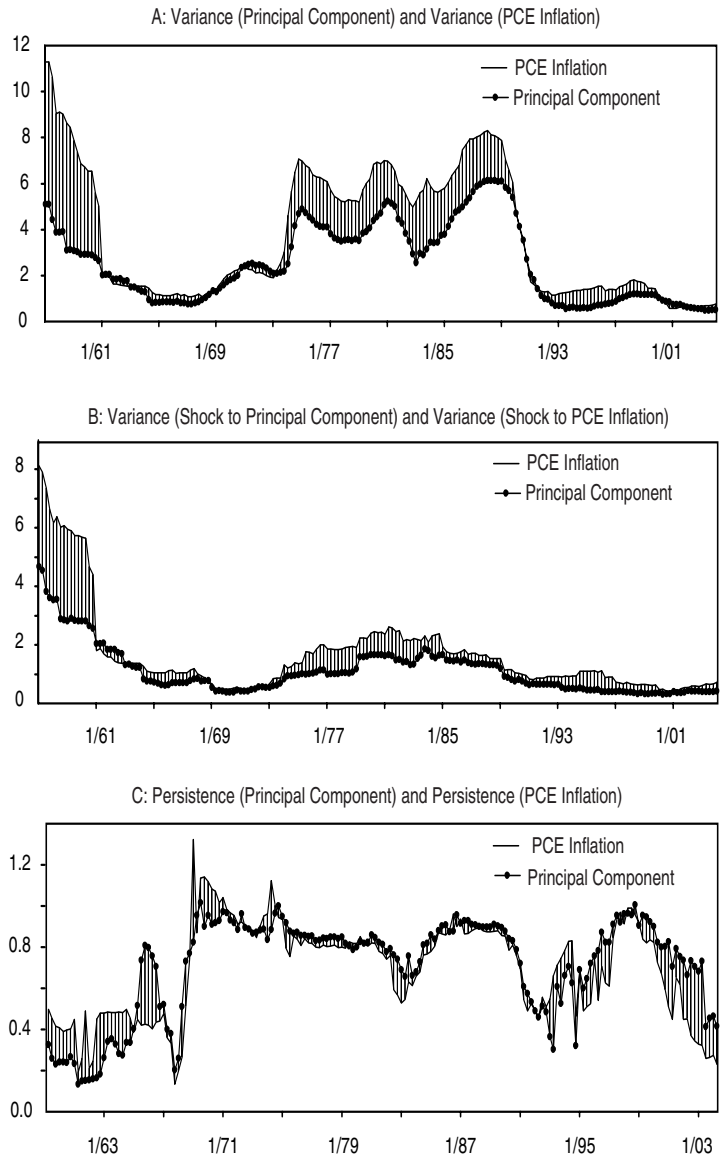
Figure 10 Volatility and Persistence of 1947 Inflation



Volatility and Persistence

Figures 10 and 11 display volatility and persistence of our alternative measures in the same way that Figure 3 displays volatility and persistence of actual inflation. Neither 1947 inflation nor the principal component of sectoral price

Figure 11 Volatility and Persistence of Principal Component



changes displays markedly different volatility patterns than does actual inflation. There are some minor differences across the series, however. Figures 10 and 11 confirm that the principal component has lower volatility than actual inflation or 1947 inflation. The inflation shock volatility displayed in the middle

panels behaves similarly for actual inflation and the principal component, declining smoothly from the mid-1970s until the early 1980s. In contrast, for 1947 inflation, there is a sharper decline in shock volatility, and it does not occur until the mid-1980s.

Rolling-window estimates of inflation persistence for the two new series are in the bottom panels of Figures 10 and 11. Over the first two-thirds of the sample, there is little difference between the persistence of 1947 inflation and the persistence of PCE inflation. This similarity is to be expected, because the underlying inflation series for the two figures do not differ much from each other. Since 1990, however, the two sets of estimates have diverged noticeably. For PCE inflation, persistence has been generally high over this period (with an average of 0.63), declining below 0.50 only in the last four years. In contrast, persistence of 1947 inflation has been generally *low* since 1990, averaging 0.45.

To some degree, the lower level of persistence in recent years for 1947 inflation is easy to explain. Nondurables has generally been the least persistent component of inflation (see Figure 7)—at least during the second half of the sample; therefore, because our 1947 inflation series places a relatively higher weight on nondurables later in the sample, this direct effect will make 1947 inflation more persistent than PCE inflation. However, this direct effect cannot explain all of the differences between the persistence of 1947 inflation and PCE inflation. The persistence of 1947 inflation is *not* simply the expenditure-share-weighted average of the persistence of the components. Our persistence measure has the flavor of a covariance, and, as such, it depends in a complicated manner on the covariance between sectoral rates of price change.

The bottom panel of Figure 11 plots the same rolling-window estimate of persistence for the principal component. Unlike 1947 inflation, the principal component places a very low weight on nondurables. Thus, it is not surprising that its persistence behaves quite differently than that of 1947 inflation. Although persistence of the principal component has declined in recent years, the decline has been smaller in magnitude than that of actual inflation; the relatively high weight on durables means that the increase in persistence of price changes of durables is reflected more in the principal component than in 1947 inflation. More generally, fluctuations in the persistence of the principal component have been smaller than fluctuations in the persistence of actual inflation or 1947 inflation.

4. CONCLUSION

We began by noting the dramatic changes in consumption expenditure shares that have occurred in the United States over the last 50 years. The fact that these shares serve as weights in consumption price inflation measures then led us to investigate the quantitative importance of shifts in expenditure shares for

the behavior of U.S. inflation. Using two different methods, we found that controlling for expenditure share changes led to a picture of U.S. inflation over the last 50 years that was somewhat—but not dramatically—different from the picture provided by actual PCE inflation. This analysis is exploratory only. That changing expenditure shares do not account for much of the behavior of inflation does not mean that those changes are inconsequential for monetary policy. Large changes in expenditure shares, together with trend changes in relative prices across sectors (as displayed in Figure 6) may interact with other differences across sectors in a way that has important implications for monetary policy. For example, if the nature of price stickiness differs systematically across sectors (as tentatively suggested by the work of Bils and Klenow [2004]) or if money demand varies systematically across expenditure types, then the monetary policy prescriptions from one-sector models may differ markedly from those in models with multiple categories of consumption.

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