Executive summary. Inflation is a fundamental macroeconomic risk factor for a broad range of asset classes. Since the 1980s, global inflation has generally trended lower and inflation shocks have become less persistent despite, at times, considerable commodity-price volatility. This shift toward lower and more stable inflation is among the most significant global economic developments of the past several decades.

In the years ahead, a critical question for investors will be whether the trend can persist in the face of secular inflationary forces, including high energy prices, fiscal and trade imbalances, demographic dynamics, and the rapid industrial development of China, India, and other emerging-market economies.

In this paper, we examine the evolving dynamics of inflation in the United States. We attribute the profound changes in U.S. inflation persistence to more effective and credible monetary policy, rather than “globalization” or other structural changes in the economy.

Our empirical analysis implies that a low and more stable inflation environment is highly likely to persist, conditional on appropriate monetary policy. We then discuss the potential implications for future short-term interest rates, long-term bonds, and inflation-hedging instruments.
Introduction

Inflation is a fundamental macroeconomic risk factor for a broad range of asset classes. Indeed, unexpected shocks to an economy’s inflation process, or changes in inflation expectations, can significantly influence the level of interest rates and, by extension, the expected returns on stocks, bonds, and other financial assets. And, although stocks and bonds have proven to be an effective long-term inflation hedge, periods of unexpectedly high and volatile inflation—such as those observed in the mid-1970s and early 1980s—have historically been associated with below-average or even negative portfolio returns.

Since the 1980s, of course, global inflation has generally trended lower (see Figure 1). Inflation volatility has also declined markedly over the decade, despite notable volatility in commodity prices at times.

This shift toward lower and more stable inflation is among the most significant global economic developments of the past several decades. In the years ahead, a critical question for investors will be whether the trend can persist in the face of secular inflationary forces, including high energy prices, fiscal and trade imbalances, demographic dynamics, and the rapid industrial development of China, India, and other emerging-market economies.

In this paper, we explore the empirical evidence regarding the evolving dynamics of inflation. We focus on U.S. inflation, although our analyses and conclusions are relevant for other major industrialized economies. In particular, we document the changes in inflation persistence in recent years and examine the role that various forces have played in this transformation. We then consider the potential investment implications of these profound changes in inflation dynamics.

Figure 1. Globally, inflation has generally become lower and less volatile over time

Inflation rates across industrialized countries

Inflation volatility across industrialized countries

Source: International Monetary Fund.
The decline in inflation persistence

A condition of inflation stability is that price shocks to the economy (e.g., a spike in energy prices) tend to evaporate quickly so that the rate of inflation reverts to its initial level. In other words, inflation becomes less persistent.

We can measure how inflation persistence has varied over time by estimating the time-series dynamics of inflation in state-space form. Figure 2 reports persistence estimates for two measures of U.S. inflation:

(1) the headline Consumer Price Index (CPI), and (2) the core CPI, which excludes the more-volatile food and energy prices.

Figure 2 shows that U.S. inflation was extremely persistent in the 1960s and 1970s. The persistence estimates peaked in 1979, the year Paul A. Volcker became chairman of the Federal Reserve Board. With the persistence estimates near 1 at that time, shocks to inflation had long-lived effects on future inflation rates. Since the early 1980s, inflation persistence has steadily declined.

Figure 2. U.S. inflation has become less persistent over time

Notes: Following Beechey and Österholm (2007), we estimate the monthly year-over-year CPI inflation rate \( \pi \) as an autoregressive 12th-order moving-average process with an unobserved, time-varying state variable for inflation persistence, \( \rho_{ss} \), such that:

\[
\pi_t - \pi^* = \rho_{ss} \pi_{t-1} - \pi^* + u_t + \sum_{j=1}^{12} \theta_j u_{t-j},
\]

where inflation persistence evolves according to a random-walk process \( \rho_{ss} = \rho_{ss,t-1} + w_t \). The central bank’s inflation target \( \pi^* \) is constant in this specification, with the time variation in \( \rho_{ss} \) capturing changes in inflation dynamics. The bold line in the figure represents the smoothed state-space maximum-likelihood estimate for parameter \( \rho_{ss} \), and the dashed lines reflect two root mean squared error bands. Persistence estimates begin in January 1955 for headline CPI, and January 1960 for core CPI.

Source: Vanguard Investment Counseling & Research.

1 Conversely, in a rising-inflation regime, the effects of inflation shocks persist, meaning that the levels of both actual and expected inflation stay higher for longer periods. Such regimes often involve economies with less-than-credible central banks and monetary policies.

2 Using different statistical techniques, Cecchetti et al. (2007) find a similar switch from largely permanent to more transitory movements in the inflation rates of other industrialized countries.
How have inflation dynamics changed?

Plausible explanations for the high persistence in U.S. inflation observed before the early 1980s include an overly accommodative response to commodity-price shocks by the Federal Reserve and poorly anchored inflation expectations (i.e., Orphanides and Williams, 2005). Some economists also suggest that globalization has been a potent force in the decline of inflation persistence.

Of course, to better explain why U.S. inflation has become lower, less volatile, and less persistent, we must first investigate how the relationship between U.S. inflation and those factors that influence it may have changed.

Consider that the macroeconomic drivers of inflation can be classified into five broad categories:

- Economic resource utilization (e.g., unemployment rate, output gap, labor costs).
- Commodity-price shocks (e.g., oil prices).
- Foreign-exchange or import-price shocks.
- Inflation expectations (a proxy for the credibility of monetary policy).
- Past or lagged inflation (a proxy for backward-looking expectations).

Measures of resource utilization, or “slack,” are a fundamental ingredient in textbook inflation-forecasting models and form the basis of so-called Phillips curves. A Phillips curve is an equation that relates some measure of aggregate resource utilization to a measure of the inflation rate. Stock and Watson (1999) argue that a reasonably specified Phillips curve is the best inflation forecasting tool. Central banks also commonly employ some version of resource utilization in forecasting inflation for their interest rate decisions.

Commodity prices and foreign exchange rates—widely regarded as leading indicators of inflation—often serve as supply-shock controls in more-formal Phillips curve-based inflation forecasting models. In recent years, academic researchers have stressed the importance of incorporating explicit measures of inflation expectations in forecasting models. Macroeconomic theory dictates that inflation expectations reflect the credibility and effectiveness of a central bank’s monetary policy, and hence are a key driver of inflation. Clarida et al. (1999), for instance, advocate incorporating inflation expectations in a newer class of hybrid New Keynesian Phillips curves.

An econometric inflation model

We model the U.S. inflation process by estimating a five-equation vector autoregression (VAR) macroeconomic model using quarterly data. The VAR model includes core CPI inflation (which excludes food and energy prices), since we wish to isolate the “second-round effects” of commodity-based inflation pressures. Using the framework of a stylized hybrid New Keynesian Phillips curve, the annualized core CPI inflation rate in the VAR model evolves over time according to a weighted average of past and expected future inflation rates, plus or minus the effects of economic slack and two distinct supply-side shocks: commodity prices and foreign exchange rates.

---

3 Central banks tend to focus on core inflation in their interest rate decisions (e.g., Bernanke, 2004). Food and energy products accounted for roughly 23% of the overall CPI basket as of June 2007.
To investigate the potential time-varying relationship between U.S. inflation and these five broad categories, we estimate a one-quarter-lagged VAR model over two samples: 1969Q2–1979Q2 and 1983Q1–2006Q4.4 We exclude the quarterly observations from 1979Q3 through 1982Q4 because of the documented structural break in inflation volatility and monetary-policy regimes over this period. As is well known, Fed Chairman Volcker formally announced a change in monetary policy in October 1979, targeting money supply in order to quell high and rising inflation. The Federal Reserve did not resume targeting the federal funds rate until after the October 1982 Federal Open Market Committee meeting (Thornton, 2006).

Rather than arbitrarily selecting one macroeconomic series to represent economic “slack” in our Phillips-curve model, we define slack as the principal component of a dynamic factor model.5 Here, the “slack” variable comes from the Federal Reserve Bank of Chicago and is derived from 85 monthly macro time series.6 This principal component—hereafter referred to as the real business cycle factor—is positively correlated with those measures most commonly associated with real economic activity, including real GDP growth, employment growth, industrial output, real spending and income growth, housing construction, and (inversely) the unemployment rate. Stock and Watson (1999) find that this real business cycle factor does a better job at forecasting inflation than any individual economic time series, including the unemployment rate or a GDP-based output gap.

In the VAR, commodity-price shocks are defined as the annual inflation rate in the Commodity Research Bureau (CRB) futures price index. The foreign-exchange variable is an equal-weighted average of annual percentage changes in the value of the U.S. dollar versus five major currencies: the British pound, the Canadian dollar, the German deutsche mark, the Japanese yen, and the Swiss franc.7 Inflation expectations are measured as the median one-quarter-ahead consensus annualized inflation forecast from the Federal Reserve Bank of Philadelphia’s Survey of Professional Forecasters.8 The one-quarter-ahead inflation forecast horizon was chosen to correspond symmetrically with the one-quarter-lagged VAR specification, although the results are robust to longer inflation forecast horizons.

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4 The number of lags in the VAR was determined by lag-length information-criteria tests.
5 Dynamic factor models are a popular technique to extract the common systematic pattern, or principal component, from a large subset of correlated macroeconomic time series. Principal components can also ameliorate econometric issues often associated with VAR models, including degrees-of-freedom constraints and omitted-variable bias. For applications in modeling inflation and other macro variables, see Stock and Watson (1999) and Bernanke and Boivin (2003).
6 We have extended the so-called Chicago National Activity Index back before 1965 by using the same methodology with a smaller subset of time series.
7 This time series is highly correlated with the Federal Reserve’s trade-weighted index of the value of the U.S. dollar, which does not begin until 1973.
8 The consensus CPI inflation forecast series begins in 1981. Earlier values are represented by the Survey of Professional Forecasters’ median GDP price deflator inflation rate, as the two series are nearly identical in 1981. For earlier values, the Livingston semiannual survey of six-months-ahead inflation expectations is used.
Empirical results

Table 1 presents the results of the VAR model. Our set of five variables explains 80% or more of the variance in core inflation in each period. Nevertheless, the regression coefficients for the U.S. core inflation equation differ notably in the two samples. In the 1959–1979 sample, lagged core inflation correlates highly with the next period’s core inflation rate, consistent with the persistence results in Figure 2, on page 3. In the 1983–2006 sample, core inflation is more closely aligned with expected future inflation, although lagged inflation is still statistically significant.

Supply shocks are also statistically significant in the 1959–1979 period, as increases in commodity-price inflation and decreases in the value of the U.S. dollar led to higher core inflation. Conversely, the two supply-shock variables are statistically insignificant in the 1983–2006 sample. In fact, the rate of commodity-price inflation is negatively correlated with core domestic inflation, a relationship that is contrary to conventional wisdom. The Phillips-curve factor is not meaningfully different from zero in either sample.9

Table 1. U.S. core inflation equation from VAR model

<table>
<thead>
<tr>
<th>Variable</th>
<th>1959Q2–1979Q2 sample period</th>
<th>1983Q2–2006Q4 sample period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged core inflation</td>
<td>0.645*</td>
<td>0.327*</td>
</tr>
<tr>
<td></td>
<td>(0.10)</td>
<td>(0.09)</td>
</tr>
<tr>
<td>Inflation expectations</td>
<td>0.257*</td>
<td>0.738*</td>
</tr>
<tr>
<td></td>
<td>(0.13)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>Real business cycle factor</td>
<td>0.048</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>Commodity-price inflation</td>
<td>0.040*</td>
<td>(0.009)</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Change in value of U.S. dollar</td>
<td>(1.031)*</td>
<td>(0.106)</td>
</tr>
<tr>
<td></td>
<td>(0.28)</td>
<td>(0.10)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.397</td>
<td>(0.160)</td>
</tr>
<tr>
<td></td>
<td>(0.25)</td>
<td>(0.20)</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.86</td>
<td>0.80</td>
</tr>
<tr>
<td>Standard error of equation</td>
<td>1.11</td>
<td>0.53</td>
</tr>
<tr>
<td>F-statistic</td>
<td>101.0</td>
<td>76.8</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>(120.6)</td>
<td>(71.2)</td>
</tr>
<tr>
<td>Mean of dependent variable</td>
<td>4.38</td>
<td>3.23</td>
</tr>
<tr>
<td>Standard deviation of</td>
<td>3.00</td>
<td>1.19</td>
</tr>
<tr>
<td>dependent variable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of observations</td>
<td>81</td>
<td>95</td>
</tr>
</tbody>
</table>

Notes: Coefficients marked with an asterisk * are statistically different from zero at the 10% significance level. Standard errors are placed in parentheses below variable coefficients.

Source: Vanguard Investment Counseling & Research.

9 In results unreported here, we find that an alternative, wage-based Phillips-curve measure—unit labor costs—is also statistically insignificant, contrary to the calibrations suggested by Sbordone (2002).
Based on a variance decomposition of the VAR inflation equation shown in Table 1, we can attribute the relative importance of each of the five variables in explaining core inflation dynamics in each sample period. The changes in the three-year variance decomposition documented in Figure 3 are striking.

During the pre-Volcker regime, those factors deemed by conventional wisdom to drive the inflation process in fact did. The relative growth in real economic activity had the largest single impact on trend core inflation, a reason for the popularity of Phillips-curve inflation models among economists and policymakers. Commodity-price shocks were another significant factor, accounting for 20% of the volatility in core CPI inflation. The economically and statistically significant correlation between commodity-price shocks and future core inflation implies that sharp increases in commodity prices eventually “bled over” and translated into sharp increases in core inflation (as well as in wages and inflation expectations).

Since 1983, however, domestic core inflation has become less responsive to fluctuations in real economic activity and price-based shocks. In fact, the commodity-price and foreign-exchange factors in Figure 3 have together accounted for only 3% of core inflation volatility, versus approximately 30% in the pre-Volcker period. The reduced influence of changes in the value of the U.S. dollar on domestic core inflation is consistent with the move toward floating exchange rates in 1973 as well as with the documented sharp decline in the pass-through of exchange rates to U.S. import prices (Marazzi et al., 2006). The relative importance of the real business cycle factor has also significantly weakened since 1983, indicating that the Phillips curve has “flattened” over the past two decades.

Perhaps the most remarkable change in the U.S. inflation process is the pronounced weakening in the correlation between energy prices and future changes in core inflation. Whereas the two oil price shocks in the 1970s were associated with large jumps in core inflation, recent surges in energy prices have not had a similar effect.
A more intuitive way to illustrate the dramatic change depicted in Figure 3, on page 7, is to document the time-varying response of core inflation to a given percentage change in energy prices (that is, core inflation’s “beta” to energy-price inflation). To do so, we first replace our broader measure of commodity inflation in the VAR inflation model with the rate of consumer energy-price inflation, as defined by the CPI energy index. We then estimate our VAR model over a ten-year rolling window, beginning in 1965Q1. Figure 4 shows the rolling beta of core CPI inflation to lagged changes in the CPI energy index.

Figure 4 documents that the “pass-through” from price changes for gasoline and other energy products to U.S. core inflation has declined considerably over time, even though the magnitude of oil-price fluctuations has not. During the 1970s, the rolling beta estimates were roughly 0.2, which meant that a doubling in oil prices led to an increase of approximately 20% in core inflation over the following year. At the end of 2006, in contrast, a doubling of oil prices would have been expected to increase core inflation by less than 1%. This empirical result is consistent with the findings of Hooker (2002), and is robust to changes in model specification and energy-price measures.

As the business cycle, commodity prices, and other leading indicators of future inflation have weakened in their ability to predict core inflation over time, inflation expectations have become significantly more important in explaining both the level and volatility of core inflation. The VAR coefficient for survey-based inflation expectations in Table 1, on page 6, is nearly three times larger in the post-1982 period than in the pre-1979 period. When we aggregate the relative importance of survey-based inflation expectations and lagged past inflation in Figure 3, inflation expectations have accounted for approximately 81% of the variance in core inflation since 1982, compared with only 38% in the pre-1979 period.10

10 Lagged inflation rates can serve as a proxy for inflation expectations under certain conditions, such as when firms reset their prices and wage contracts only periodically.
Why have inflation dynamics changed?

A major implication of the shift in U.S. inflation dynamics is that inflation shocks are less likely to persist (and hence alter trend core inflation) if inflation expectations remain well-anchored. But why the dramatic change? Economists offer several theories, with these among the most prominent:

- A more energy-efficient and less commodity-intensive U.S. economy.
- Globalization.
- More-appropriate monetary policy.

The reduced influence of energy and other commodity prices on core inflation probably reflects, to some extent, the increased energy-efficiency of a more service-oriented U.S. economy. Figure 5 shows the gradual but notable decline in the amount of energy the U.S. economy consumes per dollar of real GDP. According to the Energy Information Administration, the total energy consumed has fallen from 1,744 BTUs per dollar of real GDP in 1973 to 873 BTUs in 2006, a decrease of 50%.

The globalization in the trade of goods and services could be another factor that has altered U.S. inflation dynamics. Globalization means that U.S. firms and workers face more intense foreign competition, which could help to account for any reduced sensitivity of U.S. inflation to domestic resource utilization. To date, the empirical evidence for the link between globalization and inflation is mixed and inconclusive (e.g., Ihrig et al., 2007).

Figure 5. Globalization and reduced energy intensity as potential factors in changed inflation dynamics

Notes: Trade openness is measured as the five-year moving average of the sum of exports and imports as a percentage of GDP. Oil intensity is defined as million barrels of oil equivalent per dollar of real GDP.

Source: International Monetary Fund.

11 See, for instance, Chapter 3 of the World Economic Outlook published by the International Monetary Fund (2006).
To sort out this debate, we re-estimate for the 1983–2006 period our domestic VAR inflation equation from Table 1, on page 6:

**Domestic model**
\[
\pi_t = \alpha + \beta_1 \pi_{t-1} + \beta_2 E_{t-1}(\pi_{t-1}^{SP}) + \beta_3 realpc_{t-1}^{US} + \beta_4 cprice_{t-1} + \beta_5 forex_{t-1} + \varepsilon_t.
\]

We then compare the domestic model with a global VAR inflation equation that replaces the domestic capacity or "slack" measure \(realpc_{t-1}^{US}\) with a global capacity measure:

**Global model**
\[
\pi_t = \alpha + \beta_1 \pi_{t-1} + \beta_2 E_{t-1}(\pi_{t-1}^{SP}) + \beta_3 realpc_{t-1}^{WORLD} + \beta_4 (cprice_{t-1} \cdot t_{t-1}) + \beta_5 (forex_{t-1} \cdot t_{t-1}) + \varepsilon_t.
\]

The global model also controls for the U.S. trends toward reduced energy intensity \(t_{oil}^{(oil)}\) and increased global trade \(t_{open}^{(open)}\) illustrated in Figure 5, on page 9. By interacting our commodity-price and foreign-exchange shock variables with the trends in oil intensity and trade openness, respectively, we can account for any potential time-varying changes in the coefficient terms. Following Ihrig et al. (2007) and others, we define the global output gap as the deviation from a Hodrick-Prescott trend in the real GDP of countries in the OECD (Organization for Economic Cooperation and Development).12 For comparability, we replace our Stock-Watson real business cycle factor with a domestic output gap derived similarly using quarterly U.S. real GDP data.

Table 2 compares the results from our baseline “domestic” VAR inflation model with the competing “global” VAR inflation model. Overall, the “global” inflation model does not meaningfully differ from the regression results in our baseline U.S. core inflation model. From this analysis, we conclude that globalization has not directly altered the dynamics of U.S. inflation since the early 1980s.13

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12 Our empirical results are robust to alternative global output gap measures, since they are highly correlated with an HP-filtered output gap series. The correlation of our OECD output gap with deviations of real OECD GDP from an estimated potential GDP level is 64% over the 1970Q4–2006Q4 period.

13 “Globalization” may have indirectly played a larger role in lower U.S. inflation by helping to reduce and cement the long-run inflation expectations of domestic workers, firms, and investors. However, Castelnovo (2007) finds that the consensus survey measure of inflation expectations used in our analysis is not related to global capacity measures over our period of analysis.
More appropriate monetary policy is the key factor

The conduct of monetary policy is the most cogent and logical explanation for the evolution in U.S. inflation dynamics since the early 1980s, since inflation in the long run is ultimately under the control of an economy’s central bank. More-appropriate and credible monetary policy over the past two decades has resulted in better-anchored inflation expectations. The rising credibility of U.S. monetary policy in maintaining price stability has been cited by various researchers (i.e., Cecchetti et al., 2007) and leading Federal Reserve officials (i.e., Bernanke, 2007, and Mishkin, 2007) as playing the dominant role in the improved dynamics of U.S. inflation.

The Federal Reserve has been instrumental in helping to alter U.S. inflation dynamics by setting short-term interest rates more appropriately—i.e., at a level more likely to neutralize inflation shocks. Indeed, macroeconomic theory predicts that the relationship between an economy’s inflation rate and the other driving variables should change as inflation expectations adapt to changes in monetary policy.14

To better illustrate the changes in U.S. monetary policy, we can estimate interest rate policy rules. These so-called Taylor rules are simple monetary-policy guidelines that prescribe how a central bank should systematically adjust interest rates in response to developments in inflation and macroeconomic activity.15 In equilibrium, a Taylor rule dictates that the federal funds rate is “neutral,” with the U.S. economy growing at its potential and inflation equal to the Federal Reserve’s desired level.

A popular family of Taylor rules is based on the view that “optimal” monetary policy looks forward rather than backward, responding pre-emptively to year-ahead inflation expectations rather than past inflation levels.16 A forward-looking Taylor rule sets the fed funds rate $f_{t}^{opt}$ at time $t$ according to the formula:

$$f_{t}^{opt} = r' + E_{t} \pi_{t+4} + \gamma_{\pi} \cdot (E_{t} \pi_{t+4} - \pi^*) + \gamma_{y} \cdot (y_{gap} - y_{gap}^*)$$

where $r'$ is the equilibrium real fed funds rate and $\pi^*$ is the Federal Reserve’s long-run inflation target. According to this rule, the Federal Reserve would adjust the fed funds target with reference to how far inflation expectations $E_{t} \pi_{t+4}$ deviate from a long-run inflation target $\pi^*$, and whether the U.S. economy is expanding above or below its potential $y_{gap}$. In equilibrium, the inflation-expectations gap and output gap terms are zero, leaving the “neutral” fed funds rate as the sum of $r' + \pi^*$.

How aggressively the Federal Reserve should respond to the gaps in expected inflation and real output is a matter of debate. We can, however, estimate how the Fed has actually responded to such gaps in real time. By rearranging the above expression, we estimate the following equation:

$$f_{t}^{actual} = r' + \gamma_{\pi} \cdot (E_{t} \pi_{t+4} - \pi^*) + \gamma_{y} \cdot (y_{gap} - y_{gap}^*) + \epsilon_{t}.$$  

Macroeconomic theory and calibration suggest that the parameters necessary to achieve the Federal Reserve’s long-run goals are $\gamma_{\pi}^{actual} = 1.5$ and $\gamma_{y}^{actual} = 0.5$. According to this rule, the Fed should respond to the gap between the public’s inflation expectations and its own inflation target by raising the federal funds rate by a factor greater than one. That is, real short-term interest rates should be “restrictive” and thus should rise whenever public inflation expectations rise.

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14 This is more formally known as the Lucas critique, after the seminal work of Nobel Prize-winner Robert Lucas. Incidentally, Roberts (2006) argues that changes in the way the Federal Reserve conducts monetary policy, through its response to inflation shocks and the improved transparency of its communications, account for changes in Phillips curve-based inflation models, such as the drastic change we document in Figure 3.

15 For an overview of Taylor rules, see Orphanides (2007).

16 See, for instance, Clarida et al. (1999) and Orphanides (2001). Our specification abstracts from an interest rate smoothing parameter.
We investigate how the actual conduct of U.S. monetary policy has changed over time by estimating the above equation. We must take care, however, to analyze historical interest rate decisions in light of the information that was available to Federal Reserve officials at the time of their deliberations. Orphanides (2001) shows that real-time Taylor-rule policy recommendations differ considerably from those obtained using data revised ex post. Figure 6 reveals that this criterion is especially important for the variable $\gamma^{\text{gap}}$. As a result of data revisions and the statistical filter commonly used to impute gap measures, output gaps calculated in real time from as-reported data can differ substantially from output gaps that are estimated today for some distant past period.

In our analysis, we consider three alternative real-time measures for the output gap. We define the variable $E_t(\pi_{t+4}^e)$ as the median year-ahead consensus survey inflation forecast from the Federal Reserve Bank of Philadelphia’s Survey of Professional Forecasters. In our regressions, we control for the lag when data are released publicly. We estimate real-time forward-looking Taylor rules for two periods: (1) the pre-Volcker regime from 1965Q1 to 1979Q2, and (2) the post-1982 period, using Generalized Method of Moments (GMM).

The results in Table 3 reveal a sharp difference in how monetary policy was conducted in the two periods. The forward-looking Taylor rule does not explain monetary policy very well for the pre-Volcker regime, with adjusted $R^2$ at or below 17%. Most notably, the coefficient on the inflation expectations gap is well below 1.5; in fact, it is not statistically different from zero, regardless of how we quantify the real output gap. These results confirm that during the 1960s and 1970s, the Federal Reserve maintained short-term interest rates that were too accommodative. The federal funds rate was simply too low to preserve low and stable inflation expectations.17

17 Explanations vary for why the Federal Reserve was too accommodative during the 1970s, especially under the guidance of Chairman Arthur F. Burns. Some have argued that Fed officials believed at the time that the increase in inflation since the late 1960s was due to rising federal budget deficits and that higher short-term interest rates would be insufficient to squelch rising inflation without considerable increases in unemployment. For an overview, see Clarida et al. (2000) and Bernanke (2004), and the citations therein.
Since the early 1980s, however, the Federal Reserve has been more responsive in its pursuit of price stability, and this is illustrated in Table 3. Indeed, the estimated coefficients on the inflation expectations gap are above 2, suggesting that real interest rates have risen when the public’s expectations for inflation have deviated from the Federal Reserve’s implicit long-run inflation target of 2%. A forward-looking Taylor rule more accurately characterizes monetary policy since the early 1980s, with adjusted $R^2$ slightly higher than 70%.

Our empirical results demonstrate that, since the early 1980s, U.S. monetary policy has been more focused on low and stable inflation expectations than was the case in the 1970s, a period that Taylor (1999) and Orphanides (2007) characterize as one of substantial “monetary policy mistakes.” As an example, our estimated forward-looking Taylor rule suggests that the average nominal fed funds rate should have been over 14% for the five years following the 1974 OPEC oil embargo, or approximately double the actual fed funds rate of 7% (see Figure 7, on page 14).

Table 3. Real-time forward-looking Taylor rules under different regimes

<table>
<thead>
<tr>
<th>Variable</th>
<th>1965Q1–1979Q2 sample</th>
<th>1983Q1–2006Q4 sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Payroll gap</td>
<td>Real-time as-reported ygap variable</td>
</tr>
<tr>
<td></td>
<td>Real GDP gap</td>
<td>Stock-Watson real factor</td>
</tr>
<tr>
<td>Inflation expectations gap</td>
<td>0.421</td>
<td>0.402</td>
</tr>
<tr>
<td></td>
<td>(0.53)</td>
<td>(0.55)</td>
</tr>
<tr>
<td>Real output gap (ygap)</td>
<td>0.406</td>
<td>0.059</td>
</tr>
<tr>
<td></td>
<td>(0.66)</td>
<td>(0.39)</td>
</tr>
<tr>
<td>Constant</td>
<td>5.179*</td>
<td>5.278*</td>
</tr>
<tr>
<td></td>
<td>(1.39)</td>
<td>(1.46)</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.17</td>
<td>0.12</td>
</tr>
<tr>
<td>Standard error of equation</td>
<td>1.98</td>
<td>2.03</td>
</tr>
</tbody>
</table>

Notes: GMM estimator with prewhitening, Andrews bandwidth (appropriate AR(1) given potential IR smoothing), and Bartlett kernel. Coefficients marked with an asterisk * are statistically different from zero at the 10% significance level.

Source: Vanguard Investment Counseling & Research.
Implications for investors

If inflation expectations among investors, households, and businesses remain well-anchored in the decades ahead, then future inflation shocks—whether these arise from oil prices, higher business demand, or a weaker U.S. dollar—should have relatively brief and muted effects on actual trend inflation, as has been the case over the past decade. Indeed, the increasingly important role of inflation expectations in driving U.S. inflation dynamics has the important potential to establish a *virtuous self-reinforcing cycle* of low and stable actual inflation. Current U.S. inflation dynamics have important investment implications for the future.

Implications for long-term interest rates

U.S. Treasury bond yields can be decomposed into four components: (1) inflation expectations, (2) real yields, (3) inflation risk premiums, and (4) real rate premiums. Figure 8 illustrates the high correlation between long-term interest rates and long-term inflation expectations. Over the past decade, the consensus expected long-run CPI inflation rate has remained anchored at 2.5%. Interestingly, these long-run inflation expectations more closely mirror the average U.S. inflation rate recorded over the past two centuries than they do the rates seen in the past several decades.18

Current U.S. inflation dynamics imply that the anchoring of long-run inflation expectations should engender more stable future long-term interest rates and expected long-run bond returns than those observed over the last 30 or so years. Over the past three decades, the average risk-adjusted return on long-term bonds—as represented by the Lehman Long U.S. Government/Credit Index—has significantly lagged that of their intermediate-term counterparts. Between January 1973 and December 2006, intermediate bonds have had 90% of the return of long-term bonds with only 46% of the volatility.

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18 According to data provided by the Bureau of Labor Statistics and Global Financial Data, the average annual U.S. CPI inflation rate over the period 1821–2006 was 2.1%, versus average rates of 3.9% since 1950 and 4.8% since 1970.
Of course, the relative underperformance of long-term bonds during this span is due to the run-up in inflation expectations during the 1970s and early 1980s. If monetary policy stays appropriate, such drastic underperformance should be less likely in future, given current inflation dynamics. With inflation expectations low and relatively stable, the expected return on long-term bonds should mirror their current yields, all else equal.

That said, all else equal will not hold at all times. Anchored long-run inflation expectations may not prevent long-term Treasury yields from periodically spiking should other components of long-term interest rates—in particular, real yields and inflation risk premiums—spike in the future. As Fed Chairman Ben Bernanke (2007) and others have noted, it is unclear to what extent other forces—such as global liquidity, the increased interest in liability-driven investing and pension immunization strategies, or the activity of foreign central banks—have more recently distorted nominal yields on long-dated Treasury bonds.19

Implications for short-term interest rates
More appropriate, credible, and transparent U.S. monetary policy over the past two decades has resulted in better-anchored inflation expectations, providing a supportive environment for the economy and for equity and fixed income investors. For the future, the evolution in U.S. inflation dynamics implies that the odds of a high-inflation regime have fallen. In addition, the Treasury Inflation-Protected Securities (TIPS) market provides today’s policymakers with a real-time barometer of inflation expectations that their historical counterparts simply did not have.

However, we must stress that such a virtuous cycle is not assured, and in fact is conditional on appropriate monetary policy. Indeed, an obvious risk is that the stability of inflation could lead to complacency in the years ahead. Sargent (2000) and Mishkin (2007), for instance, worry that the type of inflation seen in the 1970s could reoccur in coming decades if policymakers forget that it was precisely restrictive monetary policy that engendered a reversion of actual inflation toward its desired lower level.

19 Obtaining a more satisfying answer to what influences long-term interest rates requires a more rigorous framework. A macro-finance term structure model, for instance, can effectively decompose fluctuations in long-term bond risk premiums into various factors. This subject is beyond the scope of this paper, and will be covered in a future Vanguard research publication.
To preserve credibility, the Fed therefore must continue to respond aggressively to shocks that have the potential to engender persistent adverse effects on inflation dynamics. The practical difficulty in doing so, of course, is that the “neutral” fed funds rate is difficult to determine in real time. While the Federal Reserve’s long-run inflation target is widely believed to be approximately 2%, what is an appropriate value for the equilibrium real fed funds rate \( r^* \)?

Many economists estimate that \( r^* \) is approximately 2%, basing that figure on the difference between the nominal fed funds rate and the year-over-year headline CPI inflation rate (recall Figure 7). This estimate, when combined with a long-run inflation target of roughly 2.0%–2.5% for headline CPI, implies to some that the neutral long-run nominal fed funds rate is roughly centered in the 4.0%–4.5% range.

However, an application of our estimated forward-looking Taylor rule suggests a higher expected long-run fed funds rate. Figure 7 indicates that a 2% estimate for \( r^* \) is biased downward. Certainly the 1970s and early 1980s did not characterize a low-inflation equilibrium. For the decades ahead, the forward-looking rule suggests that a reasonable estimate for \( r^* \) is approximately 2.75%–3.5%. If that is accurate, then the neutral nominal fed funds rate lies approximately in the 4.75%–6.0% range.

Implications for inflation-hedging instruments

Should they persist, the observed changes in U.S. inflation dynamics imply that the inflation-hedging properties of commodities and related asset classes may further weaken. As we have shown, the correlation between changes in commodity prices and actual core inflation has significantly deteriorated over time as the Federal Reserve became a more effective “firebreak” for commodity-based pressures.20

The inflation-hedging properties of TIPS, on the other hand, are invariant to changes in inflation dynamics. This is because the monthly TIPS return provides compensation for actual realized CPI inflation, regardless of the source of the CPI volatility.

Of course over longer investment horizons, stocks have proven arguably the most effective inflation hedge by generating positive long-term returns well above the rate of inflation.

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20 For a detailed discussion of commodities as an asset class, consult Stockton (2007).
References


