LAURENCE BALL
*Johns Hopkins University*

DANIEL LEIGH
*International Monetary Fund*

PRACHI MISHRA
*International Monetary Fund*

# *Understanding US Inflation during the COVID-19 Era*

**ABSTRACT** This paper analyzes the dramatic rise in US inflation since 2020, which we decompose into a rise in core inflation as measured by the weighted median inflation rate and deviations of headline inflation from core. We explain the rise in core inflation with two factors: the tightening of the labor market as captured by the ratio of job vacancies to unemployment, and the pass-through into core inflation from past shocks to headline inflation. The headline shocks themselves are explained largely by increases in energy prices and by supply chain problems as captured by backlogs of orders for goods and services. Looking forward, we simulate the future path of inflation for alternative paths of the unemployment rate, focusing on the projections of Federal Reserve policymakers in which unemployment rises only modestly to 4.4 percent. We find that this unemployment path returns inflation to near the Federal Reserve's target only under optimistic assumptions about both inflation expectations and the Beveridge curve relating the unemployment and vacancy rates. Under less benign assumptions about these factors, the inflation rate remains well above target unless unemployment rises by more than the Federal Reserve projects.

*Conflict of Interest Disclosure*: Daniel Leigh and Prachi Mishra are employees of the International Monetary Fund, which conducts a review of all externally published pieces. The authors did not receive financial support from any firm or person for this paper or from any firm or person with a financial or political interest in this paper. The authors are not currently an officer, director, or board member of any organization with a financial or political interest in this paper.

*Brookings Papers on Economic Activity*, Fall 2022: 1–54 

After four decades of low US inflation, high inflation has emerged as a central economic problem of the COVID-19 era. As of September 2022, the rate of Consumer Price Index (CPI) inflation over the previous twelve months was 8.2 percent.[1] This experience has produced an outpouring of analyses of why inflation has risen and where it might be heading in the future. This paper seeks to contribute to this debate.

A central feature of our analysis is that we decompose the headline inflation rate into two components that are determined by different factors: core inflation and deviations of headline from core. We seek to explain core inflation with long-term expected inflation and the level of slack or tightness in the labor market, and to explain the noncore component of headline inflation with large price changes in particular industries. We also study the pass-through over time from these industry price shocks to core inflation, which can occur through the effects of headline inflation on wages and other costs of production.

Section I of this paper describes how we measure core inflation. Our primary measure is the weighted median inflation rate published by the Federal Reserve Bank of Cleveland, which strips out the effects of unusually large price changes in certain industries. This variable isolates the core component of inflation more effectively than the traditional core measure of inflation excluding food and energy prices, especially during the COVID-19 era, when much volatility in headline inflation has come from price changes in industries other than food and energy. In September 2022, weighted median inflation accounted for 7 percentage points of the 8.2 percent headline inflation rate.[2]

Section II studies the behavior of core inflation. A key feature of the analysis is that, following recent studies such as Furman and Powell (2021) and Barnichon, Oliveira, and Shapiro (2021), we measure the tightness of the labor market with the ratio of job vacancies ($V$) to unemployment ($U$). We find that the very high levels of $V/U$ over 2021–2022 can explain much of the rise in monthly core inflation, especially during 2022. The rest of the rise is explained by a substantial pass-through of headline inflation shocks into core inflation.

These results help us understand why persistently high inflation has been a surprise to many economists—including us (Spilimbergo and

1. US Bureau of Labor Statistics, "Consumer Price Index News Release," https://www.bls.gov/news.release/archives/cpi_10132022.htm.

2. Federal Reserve Bank of Cleveland, "Median CPI," table "% Change Past 12 Months," https://www.clevelandfed.org/indicators-and-data/median-cpi.

others 2021)—who dismissed the run-up in inflation in mid-2021 as transitory. These economists typically measured labor market tightness with the unemployment rate, which has only fallen to but not below pre-pandemic levels, and they ignored the pass-through effect that can propagate the effects of headline inflation shocks.

Section III studies the pandemic-era shocks to headline inflation—the deviations of headline from core—that have contributed to inflation both directly and through the pass-through to core. We find that three factors have been most important in explaining this component of inflation: changes in energy prices; a measure of backlogs of goods and services orders from the information services firm IHS Markit Economics, which we believe captures the widely reported problems with supply chains; and changes in prices in auto-related industries.

Section III also performs a decomposition of the 6.9 percentage point rise in headline inflation between the end of 2020 and September 2022 (from 1.3 percent to 8.2 percent). It concludes that the combination of direct and pass-through effects from headline inflation shocks accounts for about 4.6 percentage points of the rise in twelve-month inflation. A rise in expected inflation accounts for 0.5 percentage points, and the rise in labor market tightness (measured by the ratio of vacancies to unemployment) accounts for 2 percentage points.

After analyzing the inflation experience to date, we turn to what might happen in the future. We focus on the question of what costs must be incurred for the Federal Reserve to meet its goal of reining in inflation. Federal Reserve officials have predicted a soft landing in which inflation returns to their target with only a modest increase in unemployment, while pessimists such as Lawrence Summers believe that disinflation will require a painful recession with high unemployment (Mellor 2022). Which outcome is more likely?

In our view, the answer depends largely on two factors, which we discuss in section IV. One is the relationship between unemployment and vacancies—the Beveridge curve. This relationship has shifted unfavorably during the pandemic: a given level of vacancies implies a higher level of unemployment. The unemployment costs of reducing inflation will be substantial if this relationship now remains unchanged, but the costs will be lower if a normalization of the labor market moves the Beveridge curve back toward its pre-pandemic position.

The second factor concerns long-term inflation expectations. By various measures, these expectations have been well-anchored through most of the pandemic period, but they have shown hints of increasing during 2022. The costs of containing inflation will be greater if these hints turn into a significant upward trend in expected inflation. It is difficult to predict how expectations will evolve, but we try to shed light on the possibilities by estimating the response of survey measures of expectations to movements in actual inflation.

Section V presents simulations of future inflation under alternative assumptions about these issues and about the path that the unemployment rate will follow. One unemployment path that we consider is the one forecast by Federal Reserve policymakers in their September 2022 *Summary of Economic Projections* (*SEP*), which peaks at 4.4 percent in 2023 and 2024 (FOMC 2022, table 1). In this case, if we make quite optimistic assumptions about both the Beveridge curve and inflation expectations, the inflation rate falls to a level near the Federal Reserve's target by the end of 2024. For a range of other assumptions, however, inflation stays well above the target. All in all, it seems likely that policymakers will need to push unemployment higher than these *SEP* projections if they are determined to meet their inflation goal.

Research over the last two years has yielded many insights into the factors behind inflation, and we borrow a number of these ideas, as we discuss throughout the paper. We seek to synthesize much of the recent thinking about inflation in a way that allows a transparent analysis of the data, a quantification of the impact of different factors, and an informed analysis of where inflation may head in the future.

## I. Headline and Core Inflation

Our framework for studying inflation is based on a common decomposition:

$$\text{headline inflation} = \text{core inflation} + \text{headline shocks}. \tag{1}$$

Core inflation is also known as underlying inflation. We interpret this variable as a relatively slow-moving component of inflation that depends on inflation expectations and slack in the aggregate labor market, as in the textbook Phillips curve. Headline shocks—the deviations from core—are high-frequency movements arising from large price changes in particular sectors of the economy. Fluctuations in energy prices are a perennial source of headline shocks. During the pandemic, large price changes have also occurred in industries affected by shutdowns and supply disruptions, such as travel-related industries and used cars.

Here we describe how we measure core inflation and then examine the paths of headline and core inflation since 2020.

### *I.A. Measuring Core Inflation*

The traditional measure of core inflation, the one that the Federal Reserve focuses on, is the inflation rate excluding food and energy prices (XFE inflation). This measure is so common that some economists use the term “core inflation” as a synonym for XFE inflation. However, a growing body of research argues that XFE inflation is a flawed measure of the economic concept of core inflation. The XFE measure was developed in the 1970s, when changes in food and energy prices caused large fluctuations in headline inflation (Gordon 1975). Since that time, volatility in headline inflation has also arisen from large price swings in industries besides food and energy, which are not filtered out of XFE inflation, and this phenomenon has been especially pronounced during the pandemic (Dolmas 2005; Ball and others 2021).

The shortcomings of the XFE core measure have led researchers to develop a class of alternatives: outlier exclusion measures that systematically filter out large price changes in *any* industry. These measures are weighted medians or trimmed means of the distribution of industry price changes. A number of studies find that these core measures are less volatile and more closely related to economic slack than XFE inflation (Dolmas and Koenig 2019; Verbrugge 2021; Ball and others 2021).[3]

This paper focuses on one specific outlier exclusion measure of core inflation, the weighted median CPI inflation rate published by the Federal Reserve Bank of Cleveland. It is the oldest such measure, published since the 1990s, and arguably the simplest. The online appendix considers other outlier exclusion core measures, such as the trimmed mean personal consumption expenditures (PCE) deflator inflation rate published by the Federal Reserve Bank of Dallas, and the weighted median PCE deflator inflation rate published by the Federal Reserve Bank of Cleveland.

With core inflation measured by weighted median inflation, we define headline inflation shocks as deviations of headline from median. By construction, our measures of core inflation and headline shocks sum to headline inflation.

Bryan and Cecchetti (1994) discuss the rationale for outlier exclusion measures of core inflation. In their framework, a large change in a sector’s relative price affects the aggregate price level because, with costs of nominal price adjustment, large shocks to optimal prices have disproportionately

3. Similar evidence led the Bank of Canada to adopt a weighted median and trimmed mean as official measures of core inflation in 2016, replacing its CPIX measure, which is similar to XFE.

large effects on actual price changes. Removing outliers from the price distribution filters out the effects of relative price changes, thereby isolating the part of inflation determined by macroeconomic forces.[4]

The theory of core inflation has not been perfected, and more research is warranted. That said, in judging core inflation measures for present purposes, we believe that the proof of the pudding is in the eating. Throughout this paper, we find that our decomposition of headline inflation into median and deviations from median is a fruitful framework for understanding COVID-19-era inflation. We also show that much of our analysis would be infeasible if we measured core with XFE inflation.[5]

### *I.B. Headline and Core Inflation since 2020*

We focus here on inflation in the CPI; the online appendix considers the PCE deflator. Figure 1 shows the paths of headline and median CPI inflation from January 2020 through September 2022 (the latest data available as this paper is written). Panel A shows monthly inflation at seasonally adjusted annualized rates, and panel B shows inflation over the past twelve months, a statistic that is widely reported in the media.

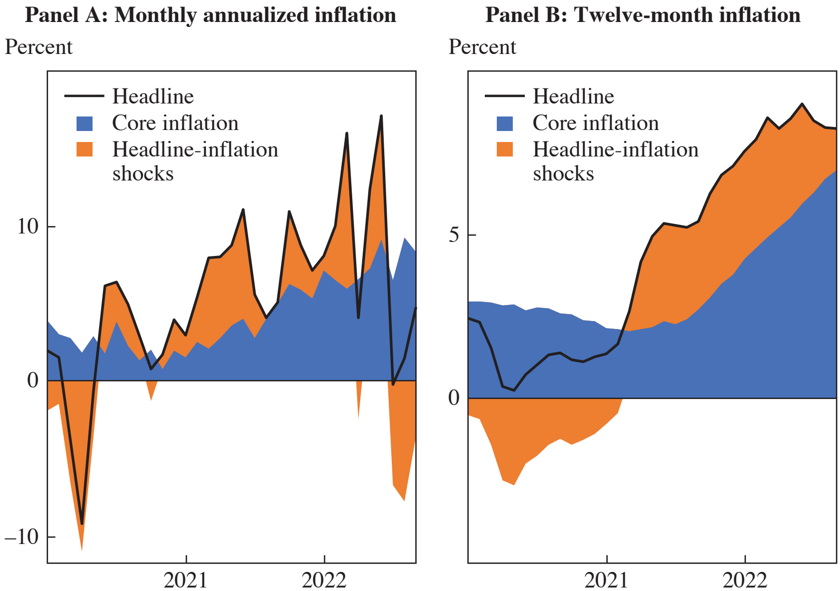
We can see from figure 1 that monthly headline inflation has been highly volatile, plunging close to −10 percent in April 2020, fluctuating up and down for the rest of that year, and coming in at 10 percent or higher at a number of points in 2021 and 2022. Monthly headline inflation soared to 17.1 percent in June 2022 and then fell to −0.2 percent in July, and it was 4.7 percent in September. The preponderance of high monthly readings in 2021 and the first half of 2022 pushed twelve-month headline inflation up to a peak (so far) of 9.1 percent in June 2022, and it was 8.2 percent in September.

Median inflation has been much less volatile, with the monthly series never changing by more than 3 percentage points from one month to the next. Median inflation drifted down in the first part of the pandemic, and as late as September 2021 the twelve-month median was still below its level in January 2020. This experience, and the common view that noncore inflation movements are transitory, helps explain the insouciance about inflation among many economists when a handful, such as Blanchard (2021) and

4. See Ball and Mazumder (2011) for more on these ideas.

5. Some economists criticize the weighted median on the grounds that the median industry is often related to housing, either rents or one of the four regional price indexes for owner-equivalent rent. However, it is not clear why it should matter which industry is the median or how much that varies.

**Figure 1.** CPI Inflation: Headline, Core, and Headline Inflation Shocks, 2020–2022




Sources: Federal Reserve Bank of Cleveland; authors' calculations.
Note: Core inflation is the weighted median CPI inflation rate from the Federal Reserve Bank of Cleveland.

Summers (2021), were first sounding an alarm. Since the middle of 2021, however, high monthly rates have led the twelve-month median to follow headline inflation upward, and it reached 7 percent in September 2022.

The following sections of the paper seek to explain this experience.

## II. Explaining Core Inflation

Our basic framework explains core inflation with three variables: expected inflation; the tightness of the labor market; and past headline inflation shocks. The first two are the variables in the textbook Phillips curve, and the third captures the pass-through of headline inflation into core inflation that may occur through wages or other costs of producing output, channels emphasized by economists such as Blanchard (2022) and di Giovanni and others (2022). In our primary specification, expected inflation is measured by ten-year forecasts from the Survey of Professional Forecasters (SPF), labor-market tightness by the average ratio of job vacancies to unemployment (*V/U*) over the current and previous eleven months, and past headline shocks by the average deviation of headline from median inflation over the current and previous eleven months.

Our findings include the following:

- A core inflation equation estimated with pre-pandemic data provides a good fit to the path of core inflation during the pandemic. The increase in core inflation during 2021 and 2022 is explained by a combination of a rise in the *V/U* ratio to unprecedented levels and pass-through from adverse headline shocks, with the role of *V/U* increasing over the last year.
- There is some evidence of nonlinearity in the effect of *V/U* on core inflation, with a large positive marginal effect when *V/U* is either above or below its usual range. There is also strong evidence of asymmetry in the pass-through effects of headline shocks, which we find are negligible for shocks that reduce headline inflation but strong for shocks that increase headline inflation.
- We can estimate the contribution of the American Rescue Plan Act of 2021 (ARP) to core inflation using estimates from Barnichon, Oliveira, and Shapiro (2021) of the ARP's effects on *V/U*. For September 2022, we find a large effect on annualized monthly inflation of 4.2 percentage points. The effect on twelve-month inflation is 1.9 percentage points and rising.
- We find that both *V/U* and past headline shocks have strong effects on nominal wage growth. These results confirm the common view that labor market tightness and headline shocks transmit into core inflation through wage adjustment.

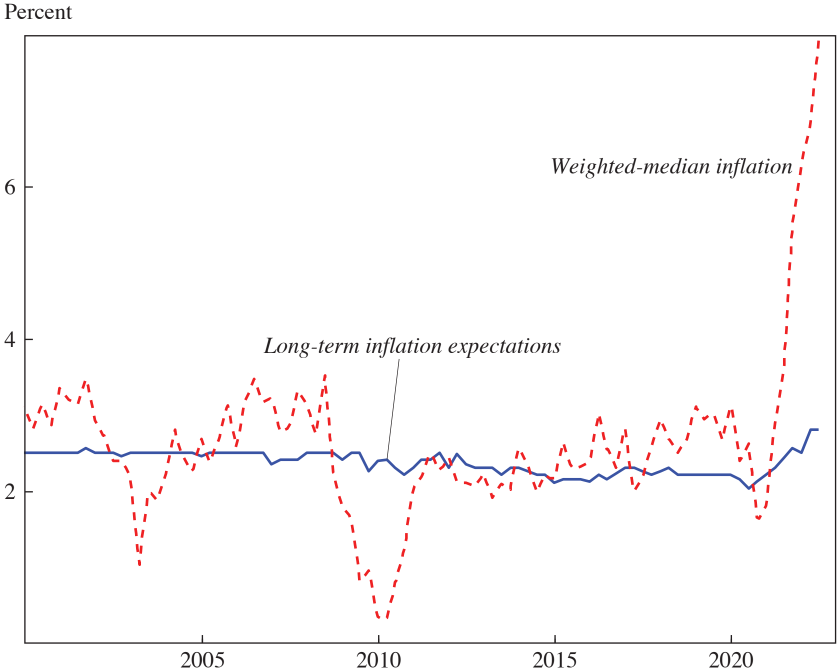
### II.A. The Role of Expected Inflation

A central tenet of mainstream macroeconomics is that the inflation rate depends strongly on expected inflation. Following studies such as Hazell and others (2022) and our own past work, we measure expected inflation with the median ten-year-ahead CPI inflation forecast from the SPF. The online appendix considers another common measure, the five-year forecast from the University of Michigan Survey of Consumers.

For the period since 2000, figure 2 shows the path of the SPF expected inflation measure along with median inflation at the quarterly frequency.[6] We see that expected inflation has been stable. During 2000–2019 expected

6. Quarterly median inflation is constructed by aggregating monthly medians as described in Ball and Mazumder (2011).

**Figure 2.** Long-Term CPI Inflation Expectations and Median CPI Inflation, 2000–2022




Source: Survey of Professional Forecasters.
Note: Ten-year-ahead CPI inflation forecasts.

inflation averaged 2.36 percent, never deviating by more than 0.3 percentage points from this level. Economists have interpreted this level of CPI inflation as consistent with the Federal Reserve's 2 percent target for PCE deflator inflation, given the systematic tendency of CPI inflation to exceed PCE inflation by several tenths of a point (the average gap is 0.3 percentage points during 2009–2019 as reported on the Federal Reserve Bank of Atlanta's Underlying Inflation Dashboard).[7] These data support the common view that expected inflation has been well-anchored over the past two decades (Yellen 2019).

That said, there has been some increase in expected inflation during the pandemic, from 2.2 percent in 2019:Q4 to 2.8 percent in 2022:Q3. This rise presumably reflects the high realizations of actual inflation during this

7. Federal Reserve Bank of Atlanta, "Underlying Inflation Dashboard," https://www.atlantafed.org/research/inflationproject/underlying-inflation-dashboard.

period. A vital question, which we discuss in section IV, is whether expected inflation will de-anchor to a larger degree in the future.

In our econometric work, we assume that core inflation responds one-for-one to movements in long-run expected inflation.[8] The dependent variable in our equations is the difference between core inflation and expected inflation, which we call the "core inflation gap." We seek to explain this variable with labor market tightness and pass-through from headline inflation shocks.

### *II.B. The Effects of Labor Market Tightness, as Measured by* V/U

Economists have long sought to explain short-run movements in the inflation rate with the level of tightness or slack in the labor market. Since Phillips (1958), the standard measure of labor market tightness has been the unemployment rate. To be sure, economists have developed more sophisticated measures that account for job vacancies and factors such as the search intensity of job seekers and firms (Abraham, Haltiwanger, and Rendell 2020) and hours of work of the employed (Faberman and others 2020). But up until the pandemic, the unemployment rate remained the most common measure of labor market tightness, in part because of its simplicity.

An important development in the last two years is that a number of inflation researchers, including Furman and Powell (2021), Barnichon and Shapiro (2022), and Domash and Summers (2022), have adopted the ratio of job vacancies to unemployment ($V/U$) rather than the unemployment rate as a simple measure of labor market tightness. This has been possible because of the data on vacancies collected since 2001 in the Bureau of Labor Statistics (BLS) Job Openings and Labor Turnover Survey (JOLTS), and Barnichon's (2010) extension of these data back to the 1950s using the help wanted index from the Conference Board. We follow this approach.[9]

The $V/U$ ratio has strong theoretical appeal as a measure of wage pressures that feed into price inflation: $V/U$ determines the threat points of the workers and firms that bargain over wages in search models (Mortensen

8. A Phillips curve specification where changes in long-run inflation expectations affect current inflation one-for-one is derived by Hazell and others (2022) in a New Keynesian framework under the assumption that shocks to the natural rate of unemployment and cost-push shocks are transitory. The authors show that under such conditions, long-run inflation expectations enter the Phillips curve with a coefficient of one.

9. Long ago, Medoff and Abraham (1982) argued that the job vacancy rate was a better measure of labor market tightness than the unemployment rate. But that paper did not have much impact on the Phillips curve literature, a likely reason being the poor quality of vacancy data before the JOLTS survey.

and Pissarides 1999). In addition, there is some evidence from the pre-pandemic era that *V/U* outperforms the unemployment rate in explaining both wage and price inflation, although the difference is not crystal clear because the two series are highly correlated (see the studies cited above and the online appendix).

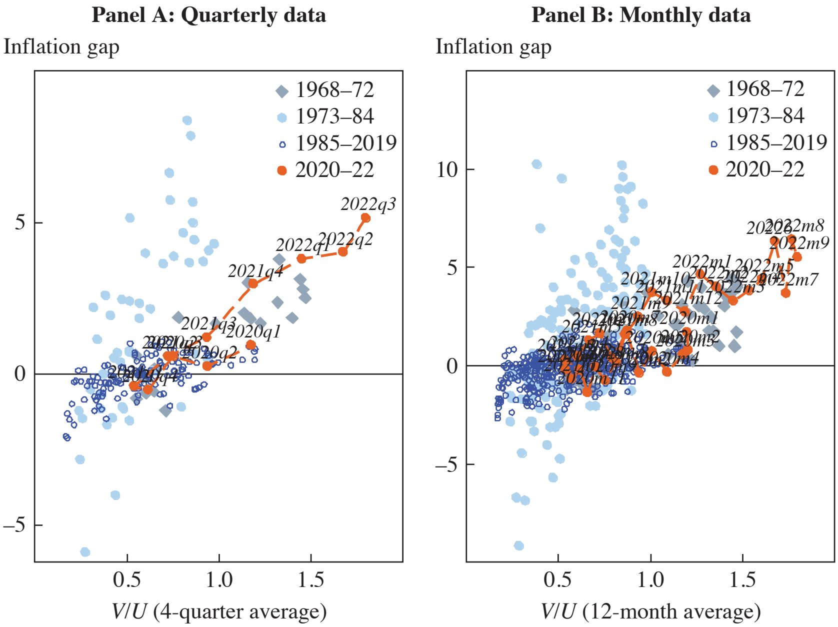
For the pandemic period, it is easier to distinguish the roles of unemployment and *V/U* because the two tightness measures have behaved differently. Over the first half of 2022, the unemployment rate averaged 3.7 percent, which is slightly above its January 2020 level (3.5 percent) and not far below the Congressional Budget Office's (CBO) estimate of the natural rate of unemployment (4.4 percent), so by that measure the labor market has not been especially tight.[10] In contrast, the average *V/U* ratio for the same period was 1.88, the highest it has been since 1951 when the Barnichon data begin. The recent levels of *V/U* imply a very tight labor market and potentially help explain the rise in inflation. (The divergence of the two tightness measures reflects a shift in the Beveridge curve relating unemployment and vacancies, which we analyze in section IV.)

COMPARING *V/U* AND THE INFLATION GAP We examine the relation between the inflation gap (median inflation minus expected inflation) and *V/U* in data back to 1968, when the Federal Reserve Bank of Cleveland's median series begins.[11] We examine both quarterly and monthly data and compare the current level of the inflation gap to an average of *V/U* over the current and previous three quarters or the current and previous eleven months. We use these averages as a parsimonious way of capturing the lags in the effects of labor market tightness that previous research typically finds. (As a robustness check, the online appendix considers the relation between the inflation gap and the current level of *V/U* alone.)

10. Bureau of Labor Statistics, "Labor Force Statistics from the Current Population Survey," LNS14000000, https://data.bls.gov/timeseries/LNS14000000; FRED Economic Data, Federal Reserve Bank of St. Louis, "Noncyclical Rate of Unemployment (NROU)," https://fred.stlouisfed.org/series/NROU.

11. Some data details: we splice the Federal Reserve Bank of Cleveland's old and new series for the median following Ball and Mazumder (2011). Data for long-term (ten-year-ahead) CPI inflation expectations come from the Federal Reserve Bank of Philadelphia website starting in 1979:Q4. These data come from the SPF starting in 1991:Q4 and from Blue Chip semiannual survey data from 1979:Q4 to 1991:Q1 (with interpolation in between surveys). For 1968:Q1 to 1979:Q3, we use forecasts from the data set on the Federal Reserve website, which are constructed from a mixture of surveys and econometric work. These forecasts are for PCE deflator inflation; we add 0.4 percentage points to obtain CPI inflation forecasts, following a rule of thumb that the Federal Reserve staff used in constructing the data set. In our monthly analysis, we use quarterly forecasts for the middle month of each quarter and interpolate between these months.

**Figure 3.** Inflation Gap versus Ratio of Vacancies to Unemployed, 1968–2022




Sources: Survey of Professional Forecasters; authors' calculations.
Note: "Inflation gap" is the difference between median and long-term expected inflation. Long-term expected inflation is the ten-year-ahead CPI inflation forecast. *V/U* denotes ratio of vacancies to unemployed (four-quarter or twelve-month average).

Figure 3 shows quarterly and monthly scatterplots of the inflation gap against the averages of *V/U*. We use different markers for the observations in four parts of the sample: 1968–1972; 1973–1984, the period of high inflation and then disinflation ushered in by the first oil shock; 1985–2019, a long period of low inflation that includes both the Great Moderation of 1985–2007 and the subsequent Great Recession and recovery; and the COVID-19 era of 2020–2022 (through 2022:Q3 or September).[12]

Notice first that the 1973–1984 period jumps out as one with unusually high inflation gaps and a steep relation between the gap and *V/U*. This anomalous behavior likely reflects the pre-Volcker monetary regime of large inflation shocks, accommodative policy, and unanchored expectations. The fluctuations in inflation are also magnified by the treatment

12. The observation for *V* in September 2022 is not available as this is written. We estimate it by simply assuming that *V* is the same in September as in August.

of housing in the CPI before 1982, which distorts inflation measurement relative to current practice when interest rates are volatile (Bolhuis, Cramer, and Summers 2022). In any case, we do not analyze this period further in this paper.

Starting in 1985, the data appear consistent with an upward-sloping relation between the inflation gap and *V/U* that is fairly stable. The observations for late 2021 and 2022 appear in the upper right of the graphs, with significantly higher gaps and a tighter labor market than at any previous time since 1985. The recent levels of the inflation gap appear roughly consistent with the unusually high levels of *V/U* and the pre-pandemic relation between the two variables.

The recent observations are also fairly consistent with those from the late 1960s, a period of overheating represented by the diamond shapes on the right sides of the graphs. That was the last period with levels of *V/U* comparable to 2021–2022, and the inflation gap reached similar levels. We believe this fact is noteworthy, although the econometric work in this paper will use only data starting in 1985 to address concerns that the structure of the economy was very different in the 1960s.

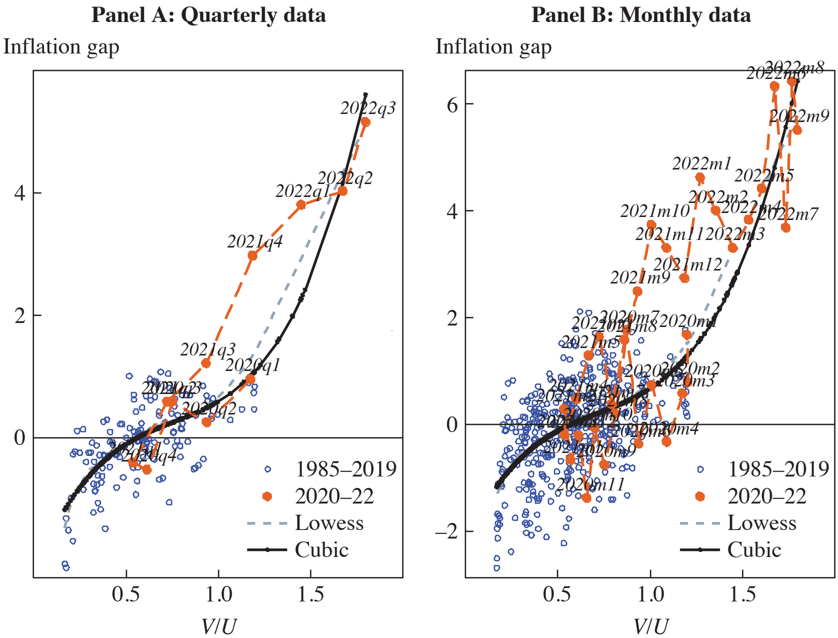
To aid in interpreting the scatterplots, figure 4 shows the results of fitting flexible curves to the data for 1985–2022. We consider a cubic function of *V/U* and a lowess estimator with a bandwidth of 0.8, which produce similar results. The data suggest a fairly flat relation for midrange levels of *V/U* and a steeper relation on either side: *V/U* has a larger marginal effect on core inflation when its level is unusually high or unusually low. The levels of the inflation gap are somewhat above the fitted curves in late 2021, but the most recent observations are close to the curves.

THE IMPORTANCE OF CORE MEASUREMENT One thing that distinguishes this paper from most inflation research is that we measure core inflation with the weighted median inflation rate. We can now see some evidence that this choice is important. Figure 5 repeats figure 3, the scatterplots of the inflation gap against *V/U*, but with core inflation measured in the traditional way with inflation excluding food and energy prices (XFE inflation). We see that the relation becomes noisier before the pandemic, and that during the pandemic XFE inflation fluctuates erratically with no clear relation to movements in *V/U*. These patterns reflect the noise in XFE inflation arising from large price changes in industries other than food and energy.

### *II.C. Pass-Through from Headline Inflation Shocks*

Many studies of core inflation, whether measured by the weighted median or by XFE inflation, seek to explain its behavior with expected inflation and

**Figure 4. Fitted Relationship: Inflation Gap versus Ratio of Vacancies to Unemployed, 1985–2022**



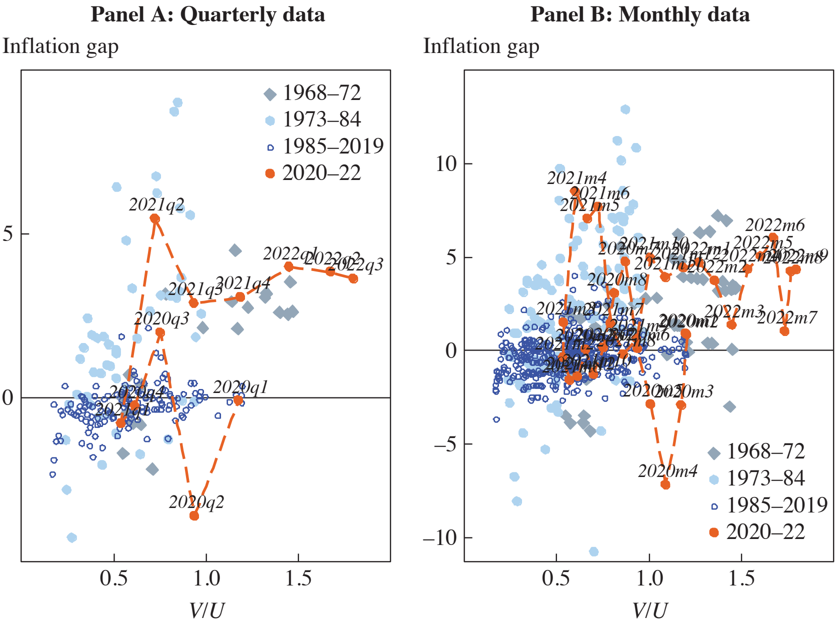

Sources: Survey of Professional Forecasters; authors' calculations.

Note: "Lowess" denotes locally weighted scatterplot smoothing strategy for fitting a smooth curve to data points. "Inflation gap" is the difference between median and long-term expected inflation. Long-term expected inflation is the ten-year-ahead CPI inflation forecast. *V*/*U* denotes ratio of vacancies to unemployed (four-quarter or twelve-month average).

slack and assume implicitly that the evolution of core inflation is unrelated to the deviations of headline from core (Spilimbergo and others 2021). Policymakers sometimes suggest that headline shocks can be ignored in analyzing and forecasting core inflation. However, some strands of the literature call this view into question, arguing that shocks to headline inflation can eventually be passed through into core inflation.

One possible mechanism, stressed by researchers such as Blanchard (2022), is wage adjustment: increases in the cost of living as measured by headline inflation influence wage demands throughout the economy and thereby contribute to core inflation. Blanchard suggests that this effect may be especially strong for large movements in inflation, which are salient to wage setters. Another pass-through channel arises because the goods and services whose price changes contribute to headline shocks are inputs into

**Figure 5.** CPI Inflation Excluding Food and Energy versus Ratio of Vacancies to Unemployed, 1968–2022




Sources: Survey of Professional Forecasters; Bureau of Labor Statistics; authors' calculations.

Note: This figure repeats figure 3, the scatterplots of the inflation gap against *V*/*U*, but with core inflation measured in the traditional way with inflation excluding food and energy prices (XFE). "Inflation gap" is the difference between XFE inflation and long-term expected inflation. Long-term expected inflation is the ten-year-ahead CPI inflation forecast. *V*/*U* denotes ratio of vacancies to unemployed (four-quarter or twelve-month average).

the production of other goods, so the price changes affect costs of production. Research at the European Central Bank (2014) stresses this effect in analyzing the transmission of oil price shocks into inflation.

We explore the effects of headline shocks as captured by the average of headline inflation minus core inflation over the same four-quarter or twelve-month period over which we measure *V*/*U* in the analysis above. This approach is consistent with European Central Bank (2014) work on oil shocks, which finds that they transmit into inflation slowly. In the online appendix we experiment with headline shocks averaged over shorter periods and find that they do not explain core inflation as well.

Pass-through effects are potentially important in the pandemic era because headline shocks have been large. The twelve-month average of these shocks has risen as high as 3.7 percentage points (in March 2022), far higher than at any point since the 1970s, although it had fallen to 1.4 percentage points as of September 2022.

### *II.D. An Equation for Core Inflation*

For the rest of this paper, we seek to explain the core inflation gap (median minus expected inflation) with four-quarter or twelve-month averages of *V/U* and headline shocks. We denote the headline shock variable by *H*. There are reasons to think that the effects of *V/U* and *H* may be nonlinear. For example, Blanchard (2022) emphasizes the salience of large shocks; Ball and Mankiw (1994) theorize that shocks have asymmetric effects in the presence of menu costs and trend inflation; and a number of studies find asymmetric pass-through effects from crude oil to retail fuel prices ("rockets and feathers").[13] Therefore, we allow for nonlinearities in a flexible way, by including cubic functions of *V/U* and *H* in the core inflation equation. Despite our nontraditional measure of labor market tightness, we call this relation the Phillips curve.

ESTIMATES Table 1 presents estimates of our Phillips curve. We report results for both quarterly and monthly data, which are similar. The data start in 1985, which is approximately the beginning of the Great Moderation period of low macroeconomic volatility (Bernanke 2004). We present estimates for the pre-pandemic period of 1985–2019 and also for that period extended to the present (2022:Q3 or September). We do not present results for the pandemic period alone, which would mean estimating seven parameters with eleven quarters of data.

For both samples, the squared and cubic terms are statistically significant for both *V/U* and *H*: the data indicate nonlinearity in the effects of these variables.[14] To aid in interpreting the results, figure 6 shows the shapes of the estimated cubic functions for monthly data from 1985 to the present, with 95 percent confidence intervals. We show the functions over the ranges of *V/U* and *H* in the data. Panel A shows the fitted values of the inflation gap as a function of *V/U* with the headline shock variable set to zero, which reveals a shape similar to that of the bivariate relation between the inflation gap and *V/U* in figure 4. Panel B shows the effect of *H* for a given *V/U*, which proves to be strikingly asymmetric: negative values of *H*, that is, headline inflation rates below median inflation, have negligible effects on

13. See, for example, Borenstein, Cameron, and Gilbert (1997) and Owyang and Vermann (2014).

14. In one case, monthly data for 1985–2019, the joint significance of the $(V/U)^2$ and $(V/U)^3$ terms is borderline ($p = 0.053$). These terms are strongly significant in quarterly data for the same period ($p = 0.012$) and in both quarterly and monthly data through 2022 ($p < 0.01$).

**Table 1. Phillips Curve Estimates: Median CPI Inflation**

| | (1) *Quarterly 1985–2019* | (2) *Quarterly 1985–2022* | (3) *Monthly 1985–2019* | (4) *Monthly 1985–2022* |
|---|---|---|---|---|
| $V/U$ | 11.039*** | 9.024*** | 9.553** | 9.140*** |
| | (3.645) | (2.120) | (4.297) | (2.234) |
| $V/U^2$ | –13.261** | –10.083*** | –10.879* | –10.328*** |
| | (5.485) | (2.383) | (6.435) | (2.545) |
| $V/U^3$ | 5.541** | 4.032*** | 4.439 | 4.241*** |
| | (2.530) | (0.789) | (2.958) | (0.863) |
| $H$ | 0.021 | 0.031 | 0.010 | 0.058 |
| | (0.068) | (0.074) | (0.073) | (0.075) |
| $H^2$ | 0.155*** | 0.081*** | 0.128*** | 0.089*** |
| | (0.041) | (0.016) | (0.035) | (0.019) |
| $H^3$ | 0.054*** | 0.026** | 0.053*** | 0.031** |
| | (0.019) | (0.010) | (0.017) | (0.012) |
| Constant | –3.026*** | –2.616*** | –2.759*** | –2.654*** |
| | (0.747) | (0.557) | (0.879) | (0.586) |
| Observations | 140 | 151 | 420 | 453 |
| $R^2$ | 0.512 | 0.761 | 0.284 | 0.575 |
| Adjusted $R^2$ | 0.490 | 0.751 | 0.274 | 0.569 |

Source: Authors' calculations.

Note: *V/U* denotes ratio of vacancies to unemployed (four-quarter or twelve-month average). *H* denotes headline inflation shock (four-quarter or twelve-month average). Newey-West standard errors with four lags (quarterly data) and twelve lags (monthly data) in parentheses.

***$p < .01$, **$p < .05$, and *$p < .10$

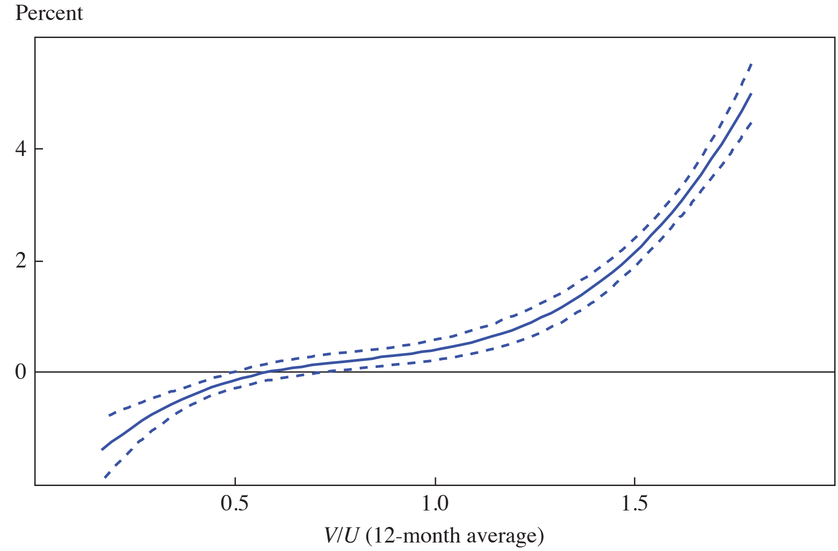
core inflation, but positive values of *H* raise core inflation. Future research should explore the sources of this asymmetry.

EXPLAINING CORE INFLATION DURING THE PANDEMIC Do the variables in our inflation equation explain core inflation during the pandemic? To address this question, we compare actual and fitted values of the monthly core inflation gap from 2020 to the present in figure 7. Panel A presents results based on the full sample from 1985 to the present and panel B based on the pre-pandemic period from 1985 through 2019. In both cases, the fitted and actual values are close to each other. Note that panel B is an out-of-sample forecast; the good fit in this case means that we can explain the pandemic experience based on the paths of *V/U* and *H* and the estimated effects of these variables in the pre-pandemic period.

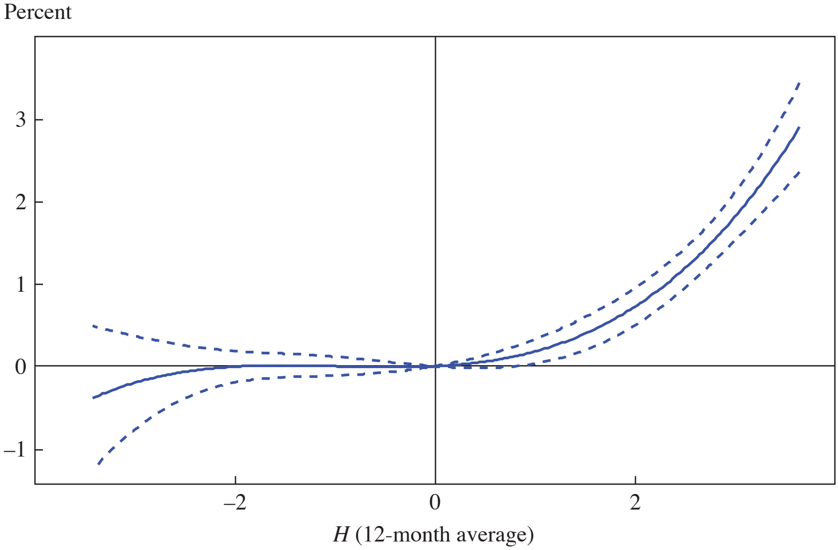
Figure 7 also shows the fitted values for the core inflation gap with the actual path of *V/U* but with the headline shock variable *H* set to zero. We interpret these paths as showing the contribution of labor market tightness to the rise in the inflation gap during the pandemic; the pass-through from headline shocks is the difference between these fitted values and those with

**Figure 6.** Estimated Inflation Gap as a Function of Slack and Headline Inflation Shocks, 1985–2022
(Percentage points; monthly data)

**Panel A: Estimated inflation gap vs. *V*/*U***



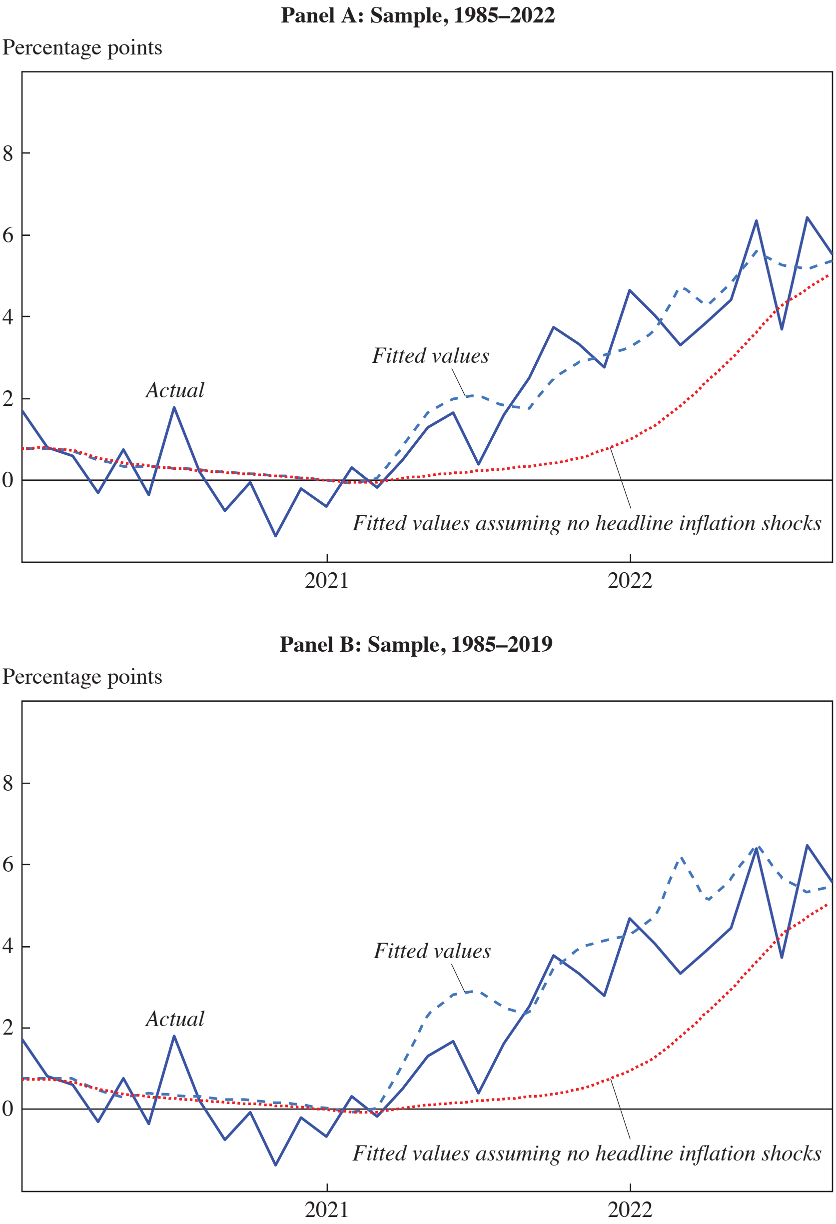

**Panel B: Estimated inflation gap vs. headline inflation shock**




Sources: Survey of Professional Forecasters; authors' calculations.

Note: Panel A reports fitted values for constant term and *V*/*U* terms from equation estimates reported in table 1 (column 4). Panel B reports fitted values for headline inflation shock (*H*) terms. Dotted lines indicate 95 percent confidence interval. Inflation gap denotes monthly annualized median CPI inflation minus long-term inflation expectations.

**Figure 7.** Predictions for Median Inflation Gap, 2020–2022




Sources: Survey of Professional Forecasters; authors' calculations.

Note: Figure reports fitted values from Phillips curve model estimated for the full sample (table 1, column 4) and for the pre-pandemic sample (table 1, column 3). Inflation gap denotes monthly annualized median CPI inflation minus long-term inflation expectations.

the actual path of *H*. We can see that the causes of rising core inflation have changed over time. Through most of 2021, there was little contribution from labor market tightness, but a strong pass-through effect pushed inflation up. In 2022, by contrast, the pass-through effect has diminished and the effect of labor market tightness has risen and become the main cause of high core inflation.

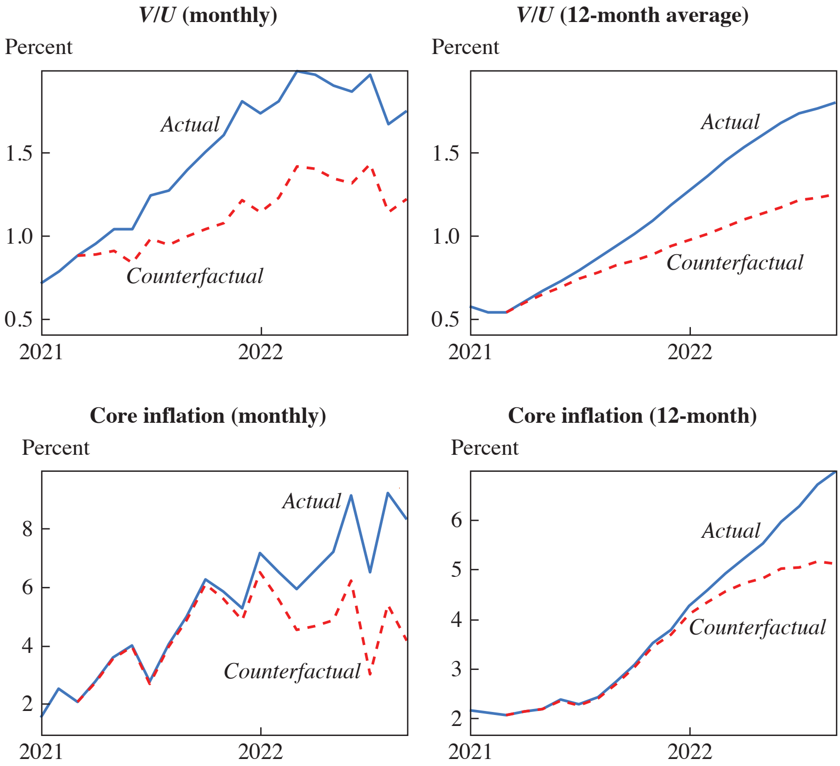
CORE INFLATION MEASUREMENT Once again, our choice of a core inflation measure is critical for our results. The online appendix reports a version of the regressions in table 1 with core inflation measured by XFE inflation. In this case, headline shocks are deviations of headline inflation from XFE inflation, which are determined by changes in the relative prices of food and energy. With these changes, we find almost no evidence of a pass-through from past headline shocks to core inflation. In addition, our core inflation equation estimated through 2019 fails to predict any rise in inflation during the pandemic era, in contrast to the equation's good performance when core is measured by weighted median inflation.

### *II.E. The Role of the American Rescue Plan*

Many economists and politicians blame the American Rescue Plan Act (ARP) passed in March 2021—the $1.9 trillion Biden stimulus plan with enhanced unemployment benefits and stimulus checks—for the overheating of the economy and rise in inflation. Our framework suggests there was some such effect: to the extent the policy stimulated demand, it presumably reduced unemployment and increased vacancies, and the higher *V/U* ratio raised inflation. Here we seek to quantify this effect.

We do not estimate the effects of the ARP on the labor market; rather, we take estimates from a previous study by Barnichon, Oliveira, and Shapiro (2021) and then derive the implied effects on inflation. The Barnichon study is useful for our purpose because it directly estimates the effects of the ARP on the *V/U* ratio. It uses methodology from Ramey and Zubairy (2018) for estimating the effects of fiscal policy based on identifying changes in government spending related to wars or geopolitical events. A caveat is that the effects on *V/U* are uncertain because pandemic-era lockdowns could have reduced the response of consumption to changes in government spending (Seliski and others 2020). Barnichon, Oliveira, and Shapiro (2021) conclude that the ARP increased *V/U* by approximately 0.6 at the end of 2021 and 0.5 at the end of 2022. We obtain a monthly path for the effects by linearly interpolating between these values. Figure 8 shows the actual path of *V/U* over 2020–2022 and the path when we subtract the effects of the stimulus.

**Figure 8.** Counterfactual Scenario without the American Rescue Plan




Source: Authors' calculations.

Note: Data on the impact of the American Rescue Plan on *V/U* come from Barnichon, Oliveira, and Shapiro (2021). Core inflation denotes median CPI inflation. Monthly inflation is annualized. The impact on core inflation derived from the Phillips curve relation estimated for 1985–2022.

Using these results, we compare the actual path of core inflation to the path in the counterfactual without the ARP. The counterfactual path is computed by subtracting the effect of the *V/U* difference in the two cases, which we compute from the relation between *V/U* and the inflation gap shown in figure 6; we assume that expected inflation is unaffected so the effect on core inflation equals the effect on the gap. We find that the difference between the two inflation paths was small in 2021 but has risen greatly in 2022. In September 2022, monthly core (median CPI) inflation is 4.2 percentage points lower in the counterfactual (4.1 percent rather than 8.3 percent) and twelve-month core inflation is 1.9 percentage points lower (5.1 percent rather than 7.0 percent). This difference amounts to about

40 percent of the rise in twelve-month core inflation from the end of 2020 to September 2022 and about one-quarter of the rise in twelve-month headline inflation.

A caveat: we have assumed that labor market tightness is the only channel through which the ARP has affected inflation. Summers suggests that the overheating of the economy arising from the ARP has helped cause supply chain problems, which in our framework can contribute to the headline shock component of inflation (Summers and Zakaria 2022). To the extent that such effects are present, our estimate of the ARP's effects on inflation should be interpreted as a lower bound.

### *II.F. Wage Inflation*

In arguing that labor market tightness and past headline shocks affect price inflation, many researchers suggest that the channels are through wages: wage inflation responds to $V/U$ and $H$, and wage inflation increases firms' costs and therefore passes into price inflation. We examine these ideas with data on wage inflation as measured by the growth rate of the employment cost index, a quarterly measure commonly used in previous work.

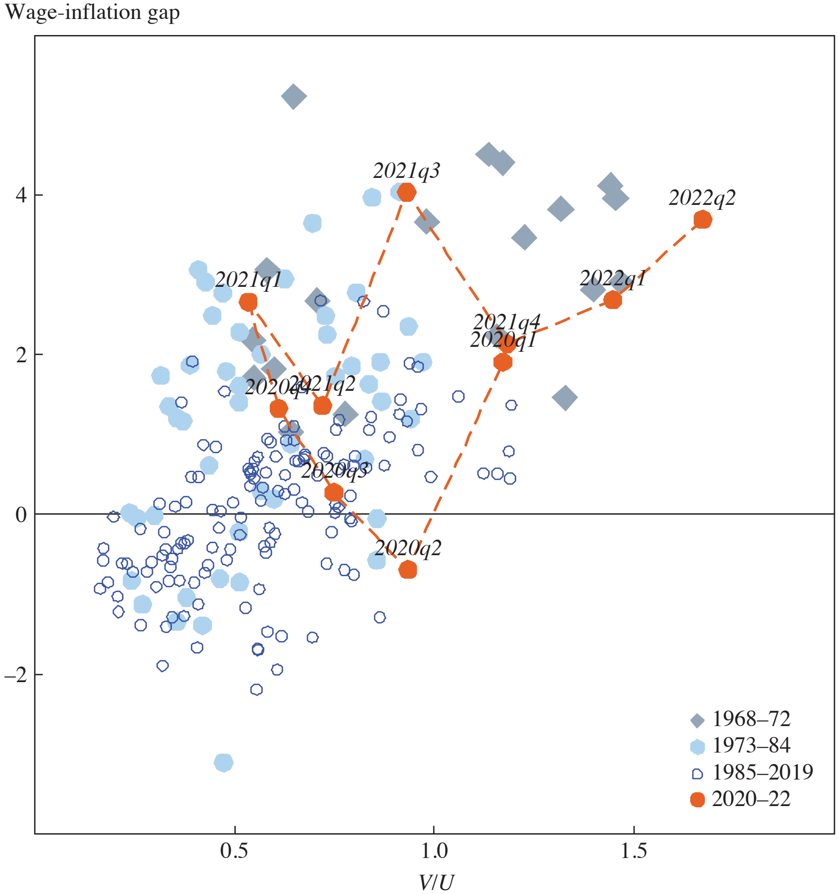
Figure 9 shows a scatterplot of the wage-inflation gap—wage inflation minus expected inflation—against the four-quarter average of $V/U$ for the period 1968–2022:Q2. We see an upward-sloping relationship, albeit one that is somewhat noisy. The relationship appears consistent across time (here, the 1970s do not jump out as unusual).[15]

To examine wage behavior more carefully, we estimate versions of the Phillips curves in table 1 with the wage-inflation gap rather than median price inflation on the left side. We again include cubic functions of $V/U$ and $H$, and following previous work on wage inflation we add a measure of trend productivity growth (output per hour in the nonfarm business sector smoothed with the Hodrick-Prescott filter with $\lambda = 16{,}000$). We present the estimated equations in the online appendix and focus here on the effects of $V/U$ and $H$ as captured in graphs.

For 1985–2022, figure 10 shows the wage-inflation gap as a function of $V/U$ (with $H$ set to zero and trend productivity set to its sample mean), and the effect of $H$, with 95 percent confidence intervals. For reference, we superimpose the relations between median price inflation and the two variables (estimated here with quarterly data). We find that the effects of

15. We leave out one big outlier: 1972:Q1, with an annualized wage increase of 13.2 percent. This increase may reflect the end of the Nixon administration's wage and price freeze.

**Figure 9.** Wage-Inflation Gap versus Ratio of Vacancies to Unemployed




Sources: Survey of Professional Forecasters; authors' calculations.
Note: "Wage-inflation gap" denotes the difference between quarterly wage inflation and long-term expected inflation. Long-term expected inflation is the ten-year-ahead CPI inflation forecast. *V/U* denotes the ratio of vacancies to unemployed (four-quarter average).

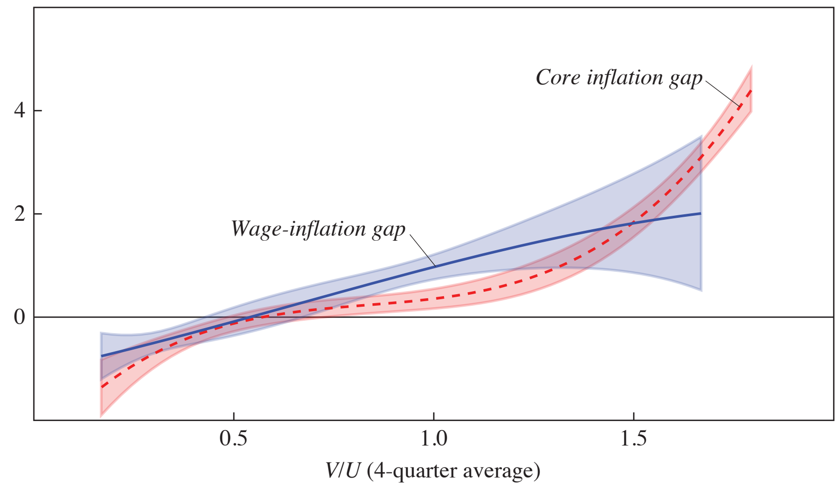
*V/U* and *H* on wage inflation are broadly similar to their effects on price inflation, consistent with the common view of transmission from wages to prices.

In contrast to our results for price inflation, the estimated effect of *V/U* on wage inflation is approximately linear. We are not sure whether this result reflects a meaningful difference between price and wage behavior, or simply the difficulty of detecting nonlinearities with noisy wage data.

**Figure 10.** Estimated Wage and Core Inflation Gaps as Functions of Slack and Headline Inflation Shocks, 1985–2022

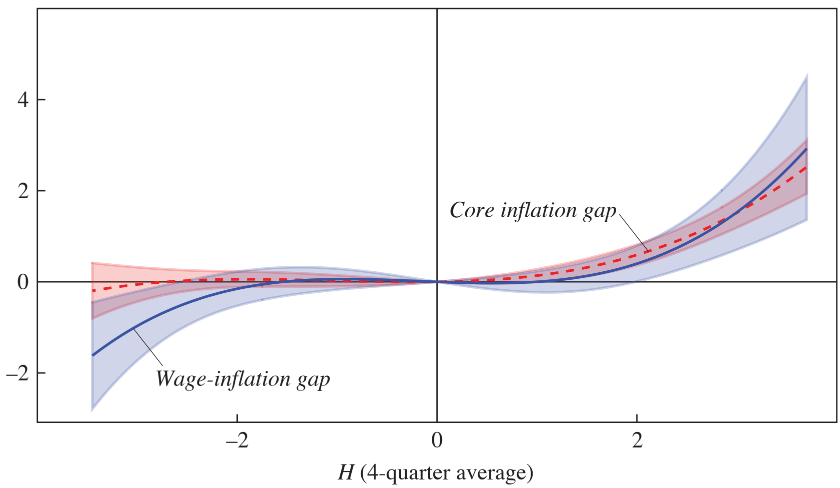
**Panel A: Inflation gap vs. *V*/*U***

Percentage points, quarterly data




**Panel B: Inflation gap vs. headline inflation shock**

Percentage points, quarterly data




Sources: Survey of Professional Forecasters; authors' calculations.

Note: For price inflation, panel A reports fitted values for constant and ratio of vacancies to unemployed ($V/U$) terms based on specification reported in table 1 (column 2); panel B reports fitted values for headline inflation shock ($H$) terms. For wage inflation, fitted values for constant, $V/U$, and productivity growth terms are based on specifications reported in online appendix table 10 (column 2) with productivity growth set at its sample mean. Inflation gap denotes quarterly core (median) CPI inflation or wage inflation minus long-term inflation expectations. Bands (shaded areas) report 95 percent confidence interval.

## III. Explaining Headline Inflation

We now examine the behavior of headline inflation, the variable that the public cares about. We first examine the causes of headline inflation shocks during the pandemic and find important roles for three variables: changes in energy prices, backlogs of orders for goods and services, and changes in auto-related prices. We then combine these results with those of the previous section to decompose the pandemic-era rise in inflation into the various factors that have influenced core inflation and headline shocks. Finally, we ask why many economists have been so surprised by the rise in inflation. Unanticipated shocks to the economy have played a role, but so have flaws in our pre-pandemic understanding of inflation drivers.

### *III.A. Explaining Headline Shocks*

Here we seek to explain the monthly deviations of headline from core inflation, which affect inflation both directly and through their pass-through to core. These deviations arise from shocks that cause large price changes in certain sectors of the economy and thereby push the mean of the price change distribution (headline inflation) away from the median. These shocks can be shifts in either industry supply (such as disruptions in the supply of oil) or industry demand (such as the fall in demand for many services at the onset of the pandemic). Unlike many studies of inflation, we do not try to estimate the relative importance of supply and demand shocks.

Large shocks occur in different sectors of the economy at different times. (That is why our core inflation measure filters out all large price changes rather than excluding a fixed set of industries.) We seek to identify the sources of headline inflation shocks during the pandemic era—the light-shaded part of the inflation decomposition in figure 1.

We explore the possible roles of many variables that are cited in discussions of pandemic-era inflation. These variables include price changes in certain sectors of the economy, such as food and energy. They also include variables that have affected multiple sectors, such as measures of the severity of COVID-19 lockdowns and disruptions in production and distribution in the economy. Table 2 presents simple regressions of headline inflation shocks on each of these variables and multiple regressions on the variables that seem most important.

In the simple regressions, the variables with the most explanatory power are, in order of importance (with adjusted $R^2$ statistics in parentheses): energy price shocks, measured as energy price inflation minus median inflation (0.646); the IHS Markit Economics index of firms' backlogs of goods and

**Table 2. Explaining Headline Inflation Shocks, 2020–2022**
(Dependent variable: Headline–Median CPI monthly annualized inflation)

*A. Bivariate regressions*

| | (1) Energy price inflation | (2) Food price inflation | (3) Harper Charter Rate | (4) Baltic Dry | (5) Supplier delivery times | (6) FRBNY Supply Chain Index | (7) Backlogs of work | (8) Goods share of real consumption | (9) Weighted average of car inflation rates | (10) COVID-19 intervention stringency |
|---|---|---|---|---|---|---|---|---|---|---|
| Coefficient | 0.064*** | –0.233 | 0.000 | 0.002*** | –0.172*** | 0.887* | 0.585*** | 2.115*** | 0.081*** | 0.033 |
| | (0.013) | (0.274) | (0.001) | (0.001) | (0.056) | (0.459) | (0.114) | (0.640) | (0.021) | (0.042) |
| Observations | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 |
| $R^2$ | 0.657 | 0.041 | 0.026 | 0.216 | 0.138 | 0.043 | 0.447 | 0.277 | 0.216 | 0.019 |
| Adjusted $R^2$ | 0.646 | 0.0104 | –0.00564 | 0.191 | 0.110 | 0.0125 | 0.429 | 0.253 | 0.191 | –0.0127 |

*B. Selected multivariate regressions*

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Energy price inflation | 0.051*** | 0.047*** | 0.056*** | 0.055*** |
| | (0.012) | (0.010) | (0.008) | (0.008) |
| Backlogs of work | 0.346*** | 0.291*** | 0.208*** | 0.203*** |
| | (0.082) | (0.063) | (0.062) | (0.061) |
| Durable goods share of real consumption | | 0.896** | | 0.215 |
| | | (0.408) | | (0.277) |
| Weighted average of car inflation rates | | | 0.068*** | 0.064*** |
| | | | (0.007) | (0.008) |
| Constant | –17.802*** | –50.165*** | –11.563*** | –19.682* |
| | (4.123) | (15.901) | (3.252) | (10.375) |
| Observations | 33 | 33 | 33 | 33 |
| $R^2$ | 0.785 | 0.827 | 0.920 | 0.922 |
| Adjusted $R^2$ | 0.771 | 0.809 | 0.912 | 0.911 |

Sources: Federal Reserve Bank of Cleveland; Harper Peterson and Co.; Baltic Exchange; IHS Markit Economics; Federal Reserve Bank of New York; Oxford Covid-19 Government Response Tracker; authors' calculations.

Note: Relative energy, food, and auto-related price inflation variables are created by subtracting median inflation from energy, food, and auto-related price inflation, respectively, and these are in monthly annualized terms. Backlogs of work variable is taken from IHS Markit Economics. Huber-White standard errors in parentheses. We do not report Newey-West standard errors because they can be unreliable in a sample as short as ours.

***$p < .01$, **$p < .05$, and *$p < .10$

services orders, which we interpret as a measure of supply chain disruptions (0.429); the share of goods in aggregate consumption, which captures the shift away from services during lockdowns (0.253); and auto price shocks, measured as a weighted average of auto-related inflation rates (new and used cars, car rentals, and car insurance) minus median inflation (0.191).

In multiple regressions, we find high explanatory power from a combination of three variables: energy price shocks, backlogs of work, and auto price shocks. A regression of headline shocks on these variables has an adjusted $R^2$ of 0.912. When all three are included, the goods share is not significant.

Figure 11 shows the actual and fitted values of headline shocks with the three key variables in the regression, along with the paths of the three variables. All three help explain the downward spike in headline inflation at the start of the pandemic, and they explain different parts of the subsequent high-inflation experience. For example, auto-related prices are important for the inflation run-up in summer 2021, the height of the chip shortage that impeded auto production. Both energy prices and backlogs help explain the 10 percentage point headline shock in March 2022. Energy prices explain the positive headline shock in June 2022 and the negative shocks from July to September.

In sum, we find that headline inflation shocks during the pandemic are well explained by some of the factors stressed in popular discussions of inflation.[16]

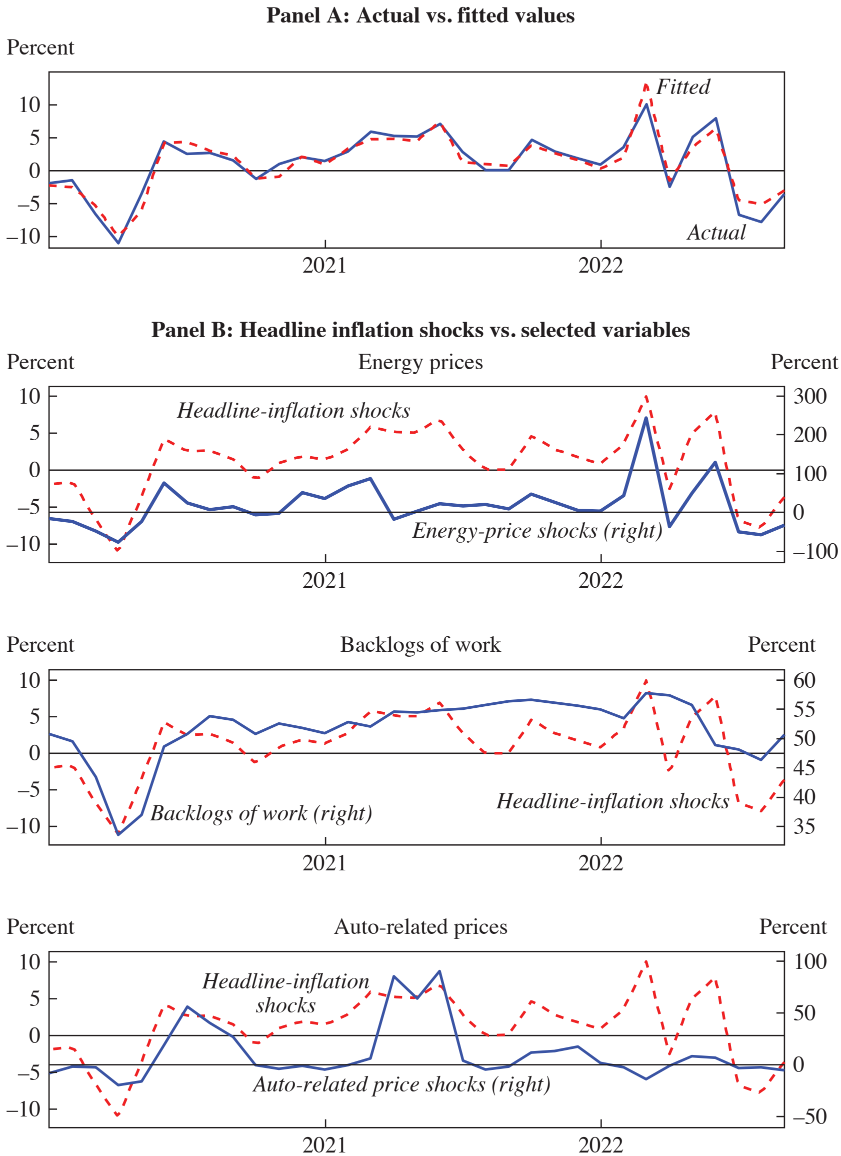
### *III.B. Accounting for the Rise in Inflation*

Having analyzed both core inflation and deviations from core, we can do an accounting of the sources of the overall rise in inflation. We compare the twelve-month headline inflation rate in September 2022, 8.2 percent, to the rate of 1.3 percent in December 2020, when the early pandemic slump had pushed inflation down. We account for the 6.9 percentage point difference between these two inflation rates. Over the same period, twelve-month core (median) inflation increased 4.6 percentage points (from 2.3 percent to 7.0 percent).

In this exercise, we use the core inflation equation (column 4 of table 1) to determine the contributions to the rise in inflation of higher expected inflation, higher levels of *V/U*, and the pass-through variable *H*. We then use

16. The energy price and auto price variables also help explain headline shocks before the pandemic, but backlogs do not. Food price inflation is significant before the pandemic but not during the pandemic (see table 2A in the online appendix).

**Figure 11.** Explaining Headline Inflation Shocks




Sources: Authors' calculations; IHS Markit Economics.

Note: In panel A, headline inflation shocks denote the difference between headline and median CPI inflation. "Fitted" denotes fitted values of headline inflation shocks from the regression in table 2, column 3. In panel B, headline inflation shocks denote the difference between monthly annualized headline and median CPI inflation. Energy and auto-related price shocks variables are created by subtracting median inflation from energy and auto-related price inflation, respectively. These variables are in monthly annualized terms. Backlogs of work variable is taken from IHS Markit Economics.

our preferred equation for headline shocks (column 3 of table 2, panel B) to determine the shares of $H$ to attribute to energy price shocks, backlogs, and auto price shocks. We use the same equation to account for the rise in the headline shock part of headline inflation. For each of the three contributors to headline shocks, we derive a total effect on the rise in headline inflation by summing the direct effect and the contribution to pass-through.[17]

Figure 12 shows the results. The combination of direct and pass-through effects of headline inflation shocks accounts for about 4.6 percentage points of the 6.9 percentage point rise in twelve-month inflation. Most of this 4.6 total reflects energy price shocks and backlogs of work, with total contributions of 2.7 and 1.7 percentage points, respectively. For each of these factors, roughly two-thirds of the contribution is the effect on current headline inflation and one-third is the pass-through into core. There is also a significant pass-through from past auto price shocks, reflecting the run-up in auto prices in summer 2021, but the direct effect on headline inflation has turned negative as these price increases have been partly reversed. A rise in expected inflation accounts for 0.5 percentage points.

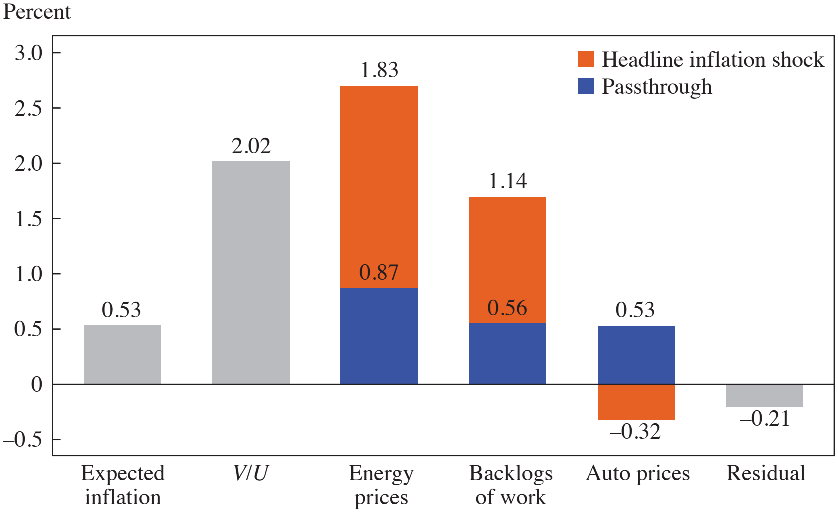
The contribution of $V/U$ to the rise in twelve-month inflation is 2 percentage points, nearly a third of the total inflation increase. However, the rise in $V/U$ explains more—nearly one-half—of the rise in *core* inflation, and as discussed above, the effect of $V/U$ is rising over time. If we decompose the change in annualized one-month core inflation from December 2020 to September 2022 (a rise of 6.4 percentage points, from 1.9 percent to 8.3 percent), the contribution of $V/U$ is 5 percentage points.

### *III.C. Why Has High Inflation Been Such a Surprise?*

As inflation began to rise in March 2021, Federal Reserve chair Jerome Powell predicted that the increase would be "neither particularly large nor persistent" (Powell 2021a). At the Jackson Hole symposium that August,

17. The details of our calculations are as follows: (1) For a given month, we decompose core inflation into expected inflation, the effect of labor market tightness, the effect of past headline shocks ("pass-through effect"), and a residual (based on table 1, column 4). (2) Next, we decompose the pass-through effect into effects of energy shocks, backlogs, auto price shocks, and another residual by using their coefficients in our headline shock equation (table 2, panel B, column 3) and the twelve-month averages of the three variables. (3) Finally, we divide the current headline inflation shock into components due to the three variables, and another residual, using the same headline shock equation ("direct effects" of the variables). Having decomposed inflation in a given month, we subtract the average of each component over January–December 2020 from the average over October 2021–September 2022 to derive the decomposition of the twelve-month inflation change shown in figure 12. We report a single residual that combines the residuals from the different steps in our calculations.

**Figure 12. Accounting for the Rise in Headline Inflation**
(Decomposition of change in 12-month headline CPI inflation from December 2020 to September 2022; percentage points)




Sources: Authors' calculations; IHS Markit Economics.
Note: The total rise in twelve-month headline inflation is 6.94 percentage points (from 1.28 percent to 8.22 percent). The total rise in twelve-month core (median) CPI inflation over this period is 4.63 percentage points (from 2.34 percent to 6.98 percent). "Expected inflation" denotes contribution of change in long-term (SPF) inflation expectations to change in headline CPI inflation. *V*/*U* denotes contribution of change in ratio of vacancies to unemployed. "Energy prices" denotes contribution of relative energy prices. "Backlogs of work" denotes contribution of change in index from IHS Markit Economics. "Auto prices" denotes contribution of weighted average of auto-related prices. Based on estimates in table 1 (column 4) and table 2, panel B (column 3).

Powell remained sanguine, noting "the absence so far of broad-based inflation pressures" (Powell 2021b, 5). Powell's view was supported by the many economists on Krugman's (2021) "Team Transitory," including the authors of this paper (Spilimbergo and others 2021). Today, it is clear that inflation was much higher than we expected.

What accounts for these forecasting errors? One factor was unexpected: adverse shocks to headline inflation. These shocks include the unusual and persistent disruption of supply chains and the rise in energy prices associated with the war in Ukraine. On the other hand, part of the problem was flaws in our pre-pandemic understanding of inflation that recent experience has made apparent. There were three intertwined problems with conventional thinking.[18]

18. The analysis here overlaps with Furman (2022).

First, economists measured labor market tightness with the deviation of unemployment from its natural rate, typically as estimated by the CBO. As a result, they neglected the tightening of the labor market captured by the dramatic increase in the ratio of job vacancies to unemployed, although this was unexpected and did not occur until late 2021.[19]

Second, many (although not all) economists assumed that the effect of unemployment on inflation was linear and fairly small, based on estimates from the pre-pandemic era of stable inflation. As a result, even when they considered the possibility of an extreme tightening of the labor market, they expected the inflationary effects to be modest. Spilimbergo and others (2021), for example, predicted that if the unemployment rate fell to 1.5 percent, core inflation would rise only to 2.9 percent.

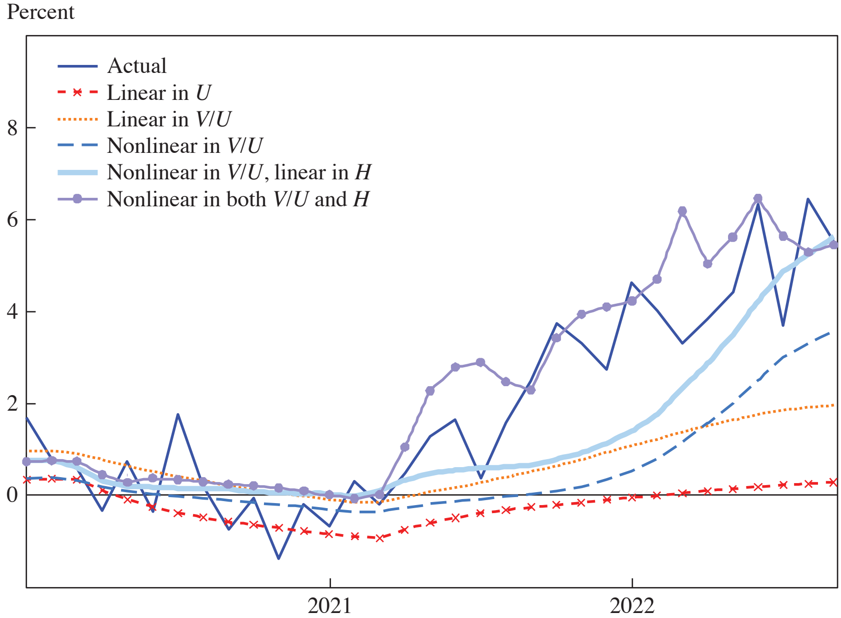
Finally, economists typically assumed explicitly or implicitly that deviations of headline inflation from core would not feed into core—they ignored the pass-through effect. If that effect had been accounted for, there would have been greater concern about core inflation in mid-2021, because at that point there had already been large headline inflation shocks, and prudent forecasters would have considered the risk of additional shocks as the economy reopened.

To illustrate these points, we compare the performance of alternative equations for monthly core inflation. We compare this paper's preferred equation to one that is linear in the twelve-month deviation of unemployment from the natural rate (as estimated by the CBO) and that excludes the pass-through variable $H$. This equation is similar to those estimated in much pre-pandemic work on the Phillips curve, including our own. To isolate the importance of different aspects of our specification, we change the traditional equation into our preferred one in steps: first replacing the unemployment measure of slack with $V/U$ while maintaining a linear relation; then using a cubic rather than linear function of $V/U$; then adding $H$ to the equation, first linearly and then as a cubic, which gives our preferred equation. We estimate each specification over the pre-pandemic era of 1985–2019 and then use the estimated equations to forecast core inflation during the pandemic.

Figure 13 shows the results. (The underlying regressions are in the online appendix.) We see again that our preferred core inflation equation performs well, as shown by the predicted path. We also see that the traditional equation with only a linear unemployment term performs quite poorly: it predicts a

19. In March 2021, the $V/U$ ratio was 0.9, well below its pre-pandemic (January 2020) level of 1.2, with little indication that it would rise to above 2.0 by March 2022.

**Figure 13.** Predictions for Median CPI Inflation Gap during the Pandemic: Comparison across Models




Source: Authors' calculations.

Note: Figure reports predicted values based on monthly equations estimated for 1985–2019 (online appendix table 13A). Our preferred core inflation equation is shown by the predicted path in short dashes with circles. The predicted values from the traditional equation with only a linear unemployment (*U*) term is reported by dashes with crosses. The other fitted values in the figure show that each of our modifications to the traditional specification—the measure of slack, nonlinearity, and the pass-through variable (*H*)—contributes to the good fit of our final preferred equation.

decrease in inflation in 2020 and almost no increase since then, reflecting the fact that the twelve-month average of the unemployment rate has not fallen much below the CBO's natural rate (currently 4.4 percent). The other fitted values in figure 13 show that each of our modifications of the traditional specification—the measure of slack, nonlinearity, and the pass-through variable—contributes materially to the good fit of our final equation.[20]

Today we can see that, even before the pandemic, inflation equations fit the data better with tightness measured by a nonlinear function of *V/U* than

20. The online appendix presents the same comparison of specifications with core inflation measured by median PCE inflation. The results are similar to those for median CPI: the traditional equation fails to predict a significant rise in inflation; our preferred specification predicts most of the observed rise (although there is some underprediction since May 2022); and the measure of slack, nonlinearity, and the pass-through variable are all important.

with a linear function of *U*, and with a pass-through effect (see table 13A in the online appendix). Before 2020, however, the evidence on these points was not striking enough to influence the inflation models of most economists. Movements in *V/U* were strongly correlated with movements in unemployment, and we did not observe the extreme labor market tightness that has made nonlinearity obvious. Headline inflation shocks were smaller and less persistent than they have been since 2020, making the pass-through effect easy to miss.[21]

## IV. Two Big Questions

We now move from explaining past inflation to considering the future. Like most economists, we presume that the Federal Reserve has the ability to rein in inflation if it raises interest rates by enough. What is less clear are the costs of doing so: Will containing inflation require a substantial slowing of the economy and increase in unemployment? Here we consider two factors that will help determine the answer: the behavior of the Beveridge curve, and the behavior of inflation expectations. There is considerable uncertainty about both issues.

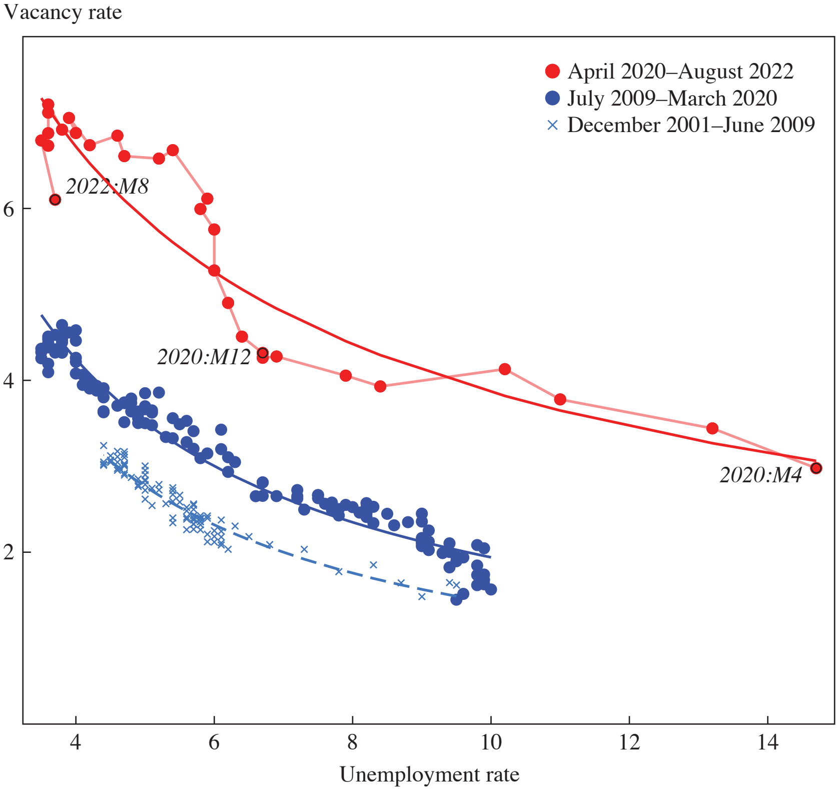
### *IV.A. The Beveridge Curve*

The Beveridge curve is the relation between the unemployment rate and the vacancy rate. It is downward-sloping, reflecting the fact that a tightening of the labor market increases vacancies and reduces unemployment. As stressed by Blanchard, Domash, and Summers (2022), the Beveridge curve determines the relation between the unemployment rate and *V/U*, and therefore affects the level of unemployment needed to reduce inflation.

THE SHIFT IN THE CURVE Figure 14 plots the unemployment and vacancy rates from 2001 through August 2022. A stable Beveridge curve appears in different periods, but the curve has shifted at discrete points in time. The curve was stable from 2001 to 2009, then shifted outward and was stable again until March 2020. With the pandemic shutdown of April 2020, the curve abruptly shifted outward by a larger amount. Initially, the shift was a jump in the unemployment rate to 14.7 percent with little change in the vacancy rate; since then, the tightening of the labor market has moved the economy up the new Beveridge curve, and recent months have seen

21. Ball and Mazumder (2021) find a pass-through effect for the euro area but fail to find one for the United States. We can now see that the negative US result reflects an assumption that the effect is linear, which the data reject.

**Figure 14.** The Behavior of the Beveridge Curve, 2001–2022




Source: Bureau of Labor Statistics.

Note: December 2001 to June 2009 covers the Great Recession and the preceding expansion, based on National Bureau of Economic Research (NBER) business cycle dates. July 2009 to March 2020 covers the pre-COVID-19 expansion and the first month of the COVID-19 era. The figure reports log-linear curves fitted to each period. Rates are given as a percentage of the labor force.

unemployment rates close to pre-pandemic levels along with very high vacancy rates.[22]

Within a regime with a stable Beveridge curve, the curve is well approximated by a log-linear relationship between the unemployment and vacancy rates. Figure 14 shows log-linear curves that we estimate for the three periods since 2001.

22. The unemployment rate is $U$/(labor force), and we define the vacancy rate as $V$/(labor force), so the ratio of the two rates equals the $V/U$ in our Phillips curve. Many researchers define the vacancy rate as $V$/(employment + $V$), but that distinction does not make a material difference for our analysis.

The outward shift in the Beveridge curve means that the labor market has become less efficient at matching unemployed workers with vacant jobs. It is not clear why that has happened, although recent work has suggested possible factors. Blanchard, Domash, and Summers (2022) cite increased reallocation of workers across firms, as captured by the gross level of hiring. Briggs (2022) cites decreased search intensity of unemployed workers, as indicated by a decline in the fraction who actively submit job applications.

Since we are not sure why the Beveridge curve has shifted, it is difficult to say whether temporary factors are responsible, in which case we should expect it to shift back at some point, or whether the shift is permanent. In August 2022, the last month shown in figure 14, *V* decreased noticeably with little change in *U*, but it is too soon to tell whether this is the start of a significant shift in the Beveridge curve. This issue is closely related to the debate between Blanchard, Domash, and Summers (2022) and the Federal Reserve's Figura and Waller (2022) about prospects for the labor market. Figura and Waller (2022) suggest that a cooling of demand can reduce the vacancy rate with little increase in unemployment, which will indeed be possible if the Beveridge curve shifts favorably. Blanchard, Domash, and Summers (2022) argue that this outcome is unlikely based on historical evidence. We will see that this issue is critical for the costs of reducing inflation.

THE RELATION BETWEEN UNEMPLOYMENT AND CORE INFLATION A log-linear Beveridge curve defines the vacancy rate $v$ is a function of the unemployment rate $u$:

$$v = au^{b},\ a > 0,\ b < 0, \tag{2}$$

which implies a relation between the ratio $V/U$ and the unemployment rate:

$$V/U = v/u = au^{b-1}. \tag{3}$$

If we substitute this expression for $V/U$ in the Phillips curve, we obtain a relation between the core inflation gap (median inflation minus expected inflation) and the unemployment rate. This relation captures the unemployment-inflation trade-off facing policymakers as they stimulate or restrain demand and thereby move the economy along a stable Beveridge curve. In addition, this relation implies that there are now two possible shocks to the Phillips curve relationship: the Beveridge curve shock in addition to the more traditional cost-push shock.[23]

We derive this trade-off for two versions of the Beveridge curve: the ones estimated for the pre-pandemic period and the pandemic period (the solid lines in figure 14). In both cases, we use the monthly Phillips curve estimated for 1985–2022 (column 4 of table 1). In this exercise we set the headline shock variable $H$ to zero.[24]

Figure 15 shows the results for the two Beveridge curves. A feature that jumps out in both cases is a striking nonlinearity: there is a sharp bend in the curve. At high unemployment rates, the relation is close to linear and flat. For example, for the pre-pandemic period, the slope is –0.28 at 8 percent unemployment and –0.31 at 6 percent, numbers that are roughly comparable to pre-pandemic estimates of the Phillips curve slope (Hazell and others 2022). However, the slope is –0.67 at 4 percent unemployment and rises dramatically to –2.8 at 3.5 percent unemployment.

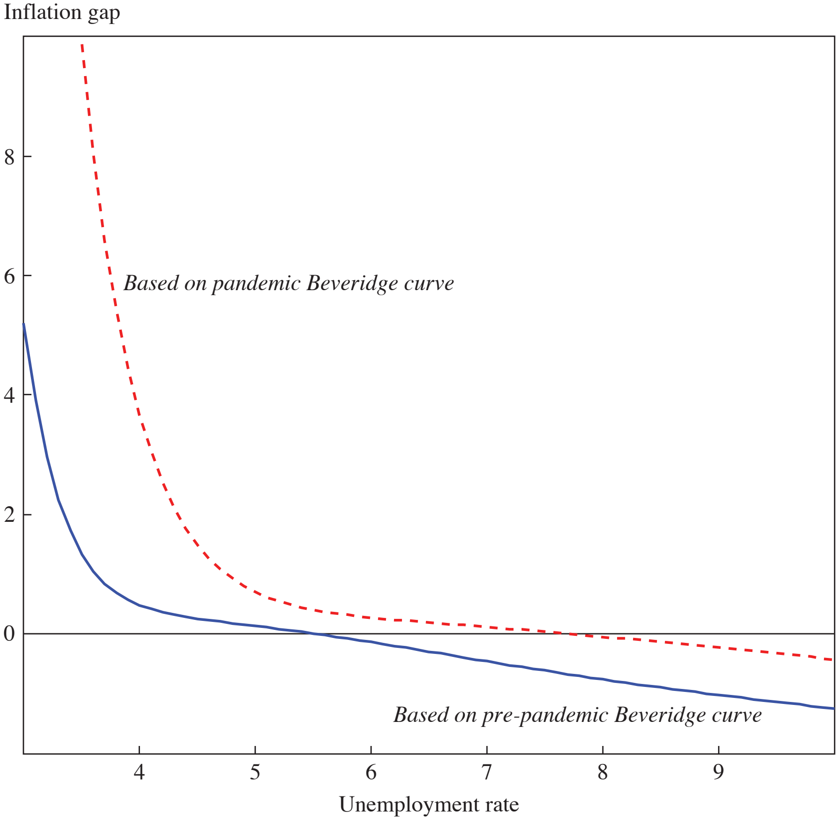
The shape of the curves in figure 15 supports Gagnon and Collins's (2019) view that the unemployment-inflation trade-off is steeper when unemployment is low. In our framework, this nonlinearity has two sources corresponding to the two relations from which the curves are derived. First, as seen in figure 6, $V/U$ has a nonlinear effect on inflation, with a large marginal effect when $V/U$ is high. Second, $V/U$ is strongly nonlinear in $U$, with a large marginal effect when $U$ is low. This second nonlinearity reflects the facts that both $1/U$ and $V$ are convex in $U$, the latter because of the shape of the Beveridge curve.

The other message from figure 15 is that the unemployment-inflation trade-off has worsened during the pandemic: the inflation rate is now higher for any given unemployment rate, especially when unemployment is low. For example, at an unemployment rate of 4 percent, the core inflation gap is 0.5 percentage points with the old Beveridge curve and 3.7 percentage points with the pandemic Beveridge curve. This difference reflects the fact that 4 percent unemployment implies a much higher $V/U$ with the pandemic curve. We will see that the shift in the unemployment-inflation trade-off,

23. These two shocks are not structural or independent. For instance, some shocks could increase production costs and simultaneously increase mismatch in the labor market. But they are also not identical: shocks to the Beveridge curve could be unrelated to cost-push shocks.

24. The estimated parameters in the Beveridge curves are $a = 13.9$ and $b = -0.85$ for the pre-pandemic (July 2009–March 2020) sample and $a = 15.5$ and $b = -0.60$ for the pandemic (April 2020–August 2022) sample. The latter period ends in August 2022 because the vacancy rate for September is not yet available.

**Figure 15.** Median CPI Inflation Gap versus Unemployment Rate for Different Beveridge Curves




Sources: Survey of Professional Forecasters; authors' calculations.
Note: "Inflation gap" denotes monthly annualized median CPI inflation minus long-term inflation expectations. Curves are derived from the estimates of the Phillips curve (table 1, column 4) and the Beveridge curves reported in the text.

if it persists, will make it costly for the Federal Reserve to reverse the pandemic-era rise in inflation.

THE NATURAL RATE OF UNEMPLOYMENT We can use the unemployment-inflation relationships in figure 15 to estimate the natural rate of unemployment and how it has changed during the pandemic. Following Friedman (1968), we define the natural rate as the unemployment rate at which actual inflation equals expected inflation. It is the unemployment rate that is sustainable in the long run.

One might think that the natural rate is the unemployment rate at which the inflation gap in figure 15—the difference between core inflation and long-term expected inflation—is zero. There is, however, a subtle complication: core inflation is *median* inflation but expected inflation is a survey measure of expected *headline* inflation, which could differ slightly from expected median inflation. Over 1985–2019, median inflation exceeded headline inflation by an average of about 0.2 percentage points (which means on average there was a slight left skewness in the distribution of industry inflation rates). We therefore assume that long-term expected core inflation is 0.2 percentage points higher than expected headline inflation. This assumption implies that the natural rate of unemployment is the rate at which the inflation gap in figure 15 is 0.2.

Based on this definition, the natural rate of unemployment is 4.8 percent for the unemployment-inflation relation derived from the pre-pandemic Beveridge curve in figure 15 and 6.5 percent for the pandemic-era Beveridge curve. The 4.8 estimate is close to other natural rate estimates for the pre-pandemic era (for example, the CBO's natural rate averaged 5.2 percent over 1985–2019). Our finding that the natural rate has risen 1.7 percentage points during the pandemic is roughly consistent with Crump and others (2022) and Blanchard, Domash, and Summers (2022), who report natural rate increases of 2.0 and 1.3 percentage points, respectively. In our framework, the increase has resulted from the outward shift in the Beveridge curve, and the natural rate will fall if the curve shifts back toward its pre-pandemic position.

We should emphasize that estimates of the natural rate of unemployment are imprecise. This is true both in general (Staiger, Stock, and Watson 1997) and in particular for our calculations because they depend on our calibration of the difference between expected median and expected headline inflation. Small changes in that number imply substantial changes in our natural rate estimates. That said, the result that the outward shift in the Beveridge curve has increased the natural rate is robust.[25]

### *IV.B. Will Inflation Expectations Remain Anchored?*

In the two decades before the pandemic, long-term inflation expectations were well-anchored at the Federal Reserve's inflation target, and

25. If we assume that the difference between expected median and expected headline inflation is zero, then the estimated natural rates for the pre-pandemic and pandemic periods are 5.5 percent and 7.8 percent, respectively. If we assume that the difference in expected inflation is 0.4 percentage points (which is the average difference between median and headline inflation in the decade before 2020), the estimated natural rates are 4.0 percent and 5.3 percent.

this anchoring made it easier to return actual inflation to target when it was pushed away temporarily. Looking forward, if expectations remain anchored, then inflation will again return to target once the labor market normalizes and the economy moves beyond the unusual shocks of the pandemic.

However, the anchoring of inflation expectations is not immutable. Anchoring has occurred because the Federal Reserve has built a track record of reversing short-run movements in inflation and returning inflation to target. Presumably a large enough and persistent enough rise in inflation would eventually lead people to revise their expectations upward, which in turn would push actual inflation even higher. That outcome would worsen the unemployment-inflation trade-off and increase the costs of reining in inflation.

There are hints that a de-anchoring of expectations may already have begun. As shown in figure 2 above, ten-year expected inflation in the SPF has risen from 2.2 percent in 2019:Q4 to 2.8 percent in 2022:Q3. Five-year expectations in the University of Michigan Survey of Consumers have risen from 2.2 percent in December 2019 to 2.7 percent in September 2022.[26]

Will these modest increases in expected inflation be reversed as the Federal Reserve takes action to control inflation? Or are we seeing the beginning of a substantial de-anchoring? It is hard to know, but we seek to inform discussions of the issue by carefully examining the response of expectations to inflation movements, both in the pandemic period and earlier.[27]

A SIMPLE MODEL OF INFLATION EXPECTATIONS We posit a simple equation in which expectations evolve in response to movements in headline inflation:

$$\pi_t^e = \gamma \pi_{t-1}^e + (1-\gamma)\pi_t, \tag{4}$$

where $\pi^e$ is expected inflation and $\pi$ is actual headline inflation. The parameter $\gamma$ captures the degree of anchoring. For $\gamma = 1$, expected inflation is constant regardless of actual inflation behavior. For $\gamma = 0$, expected inflation adjusts one-for-one with current inflation.

26. Surveys of Consumers, University of Michigan, “Times Series Data,” table 33: Expected Change in Prices during the Next 5 Years, https://data.sca.isr.umich.edu/data-archive/mine.php.

27. See also Reis (2021) and Hilscher, Raviv, and Reis (2022), who examine the distribution of expectations across individual survey respondents to assess the risk of de-anchoring.

We consider the evolution of expected inflation over some period starting at $t = \tau$. By repeatedly substituting the equation for $\pi^e$ into itself, we obtain

$$\pi_t^e = (1-\gamma)\sum_{i=0}^{t-\tau-1}\gamma^i \pi_{t-i} + \gamma^{t-\tau}\pi_\tau^e, t > \tau. \tag{5}$$

We estimate $\gamma$ with the SPF's quarterly series for ten-year expected inflation. We account for the fact that the current quarter's inflation rate is not known when a ten-year forecast is made by replacing $\pi_t$ (the first term in the summation) with the current-period (SPF) expectation of $\pi_t$, a now-cast that is reported at the same time. We denote this expectation by ${}_t\pi_t$. We also add an error term to the equation to capture other influences on expectations, yielding:

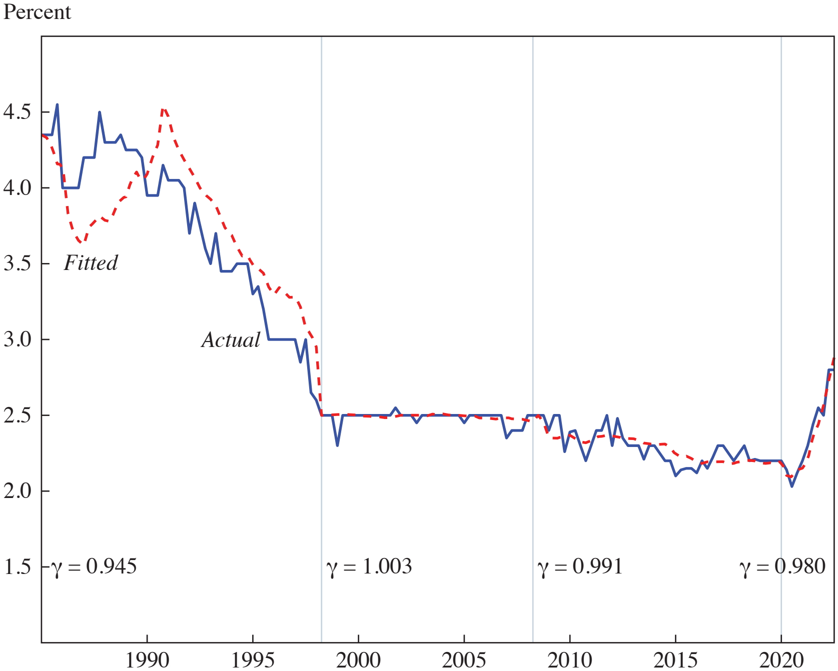
$$\pi_t^e = (1-\gamma)\,{}_t\pi_t + (1-\gamma)\sum_{i=1}^{t-\tau-1}\gamma^i \pi_{t-i} + \gamma^{t-\tau}\pi_\tau^e + \epsilon_t, t > \tau. \tag{6}$$

We estimate $\gamma$, the single parameter in this equation, with nonlinear least squares.

ANCHORING IN SEVERAL ERAS We examine the behavior of expectations in several time periods. Specifically, we divide the data from 1985 to the present into four periods for which we have reason to believe that expectations behaved differently. Figure 16 shows the path of expected inflation since 1985, the estimated $\gamma$ for each period, and the associated fitted values for expected inflation. Our results and interpretation for the four periods are as follows:

- 1985:Q1–1998:Q1: this is the period before anchoring, when the actual CPI inflation rate drifted down from about 4 percent to 2.5 percent and expectations followed. The estimated $\gamma$ is 0.945, the lowest for the four periods.
- 1998:Q2–2008:Q2: the start of this period is the beginning of the anchoring regime identified by Ball and Mazumder (2018). Actual inflation fluctuated but expected inflation was almost constant at 2.5 percent, and the estimated $\gamma$ is 1.003.
- 2008:Q3–2019:Q4: this is the period following the Great Recession, when inflation repeatedly fell short of the Federal Reserve's target, albeit by small amounts. It appears that this experience produced some de-anchoring, with expected inflation falling. The estimated $\gamma$ is 0.991.
- 2020:Q1–2022:Q3: the pandemic period in which expected inflation has risen somewhat. The estimated $\gamma$ is 0.980, suggesting that anchoring has become weaker than it was before the pandemic.

**Figure 16.** Actual and Fitted Inflation Expectations




Sources: Survey of Professional Forecasters; authors' calculations.

Note: Figure reports actual values of long-term CPI inflation expectations and fitted values for several periods from the partial-adjustment model described in the text. The parameter $\gamma$ indicates the degree of anchoring of inflation expectations in each period.

In what follows, we use these historical experiences as guides to what might happen in the future.

## V. Scenarios for Future Inflation

Where is inflation heading? We will not offer unconditional forecasts. The path of inflation will depend on how quickly the Federal Reserve raises interest rates and how those actions and other factors affect the labor market. We will leave forecasts concerning those issues to others, and forecast inflation paths conditional on paths for unemployment. This exercise will help us see how much the Federal Reserve needs to raise unemployment to return inflation to an acceptable level.

One unemployment path we consider is the one projected by members of the Federal Open Market Committee (FOMC) in their most recent

(September 2022) *SEP*. In this scenario, the unemployment rate rises only modestly from its current level, peaking at 4.4 percent at the end of 2023. We also consider a more pessimistic forecast from the International Monetary Fund (IMF)'s October 2022 *World Economic Outlook* in which (in the quarterly data underlying the report) unemployment peaks at 5.6 percent in 2024, and a much more pessimistic scenario suggested by Summers (Mellor 2022) in which unemployment rises to 7.5 percent for two years. Summers suggests that unemployment must rise that much to return inflation to the Federal Reserve's target.

Once we assume a path for the unemployment rate, there is still uncertainty about the path of inflation because it will depend on the behavior of the Beveridge curve and of expectations. We construct forecasts for both optimistic and pessimistic assumptions about these factors.

In all our simulations, we set headline inflation shocks to zero starting in October 2022. This is a natural benchmark because historically headline shocks have been unpredictable and not persistent.[28] However, it is important to keep in mind that the future could bring either positive or negative headline shocks. We might see inflationary shocks resulting from a worsening of the war in Ukraine or new disruptions of production as the pandemic waxes and wanes. We might see disinflationary shocks if energy prices fall or other supply factors improve. (Currently, oil futures curves suggest that crude oil prices are expected to decrease in coming years.) Either way, there could be major movements in inflation that are unrelated to monetary policy.

### *V.A. Alternative Assumptions about the Beveridge Curve and Expectations*

We consider the following scenarios.

THE BEVERIDGE CURVE Our pessimistic case for the Beveridge curve is that it remains in its position during the pandemic to date, as captured by the log-linear relation we have estimated (see figure 14). This means that the factors that have worsened the ability of the labor market to match workers to jobs, whatever they are, persist.

Our other scenario is that the Beveridge curve shifts back quickly to its pre-pandemic position (see figure 14). Specifically, starting from the pandemic era curve in September, the curve shifts one-quarter of the way

28. The serial correlation of headline inflation shocks is low: an AR(1) specification for the monthly headline inflation shock yields an estimated coefficient of 0.4 for 1985–2019 and 0.5 for 2020–2022.

toward its pre-pandemic position every month, which means the outward shift during the pandemic is almost entirely reversed after about six months.[29]

EXPECTATIONS We specify paths for expected inflation at the monthly frequency. In all cases we start with expected inflation in September 2022 at 2.8 percent, the level reported in the SPF for 2022:Q3. We consider three scenarios for the evolution of expectations starting in October.

In our most optimistic scenario, confidence in the Federal Reserve's commitment to low inflation ensures that expected inflation quickly reverts to its pre-pandemic level of 2.2 percent. Specifically, it moves one-quarter of the way each month.

A second scenario is that expected inflation continues to respond to actual inflation as our estimates suggest it has so far during the pandemic. That is, expected inflation follows the pandemic era process: $\pi^e_t = \gamma\pi^e_{t-1} + (1 - \gamma)\pi_t$ with $\gamma = 0.980$ at the quarterly frequency. We set $\gamma$ equal to the cube root of 0.980 in our monthly simulations.

Finally, we consider a variation on the second scenario with $\gamma = 0.944$ at the quarterly frequency, which is the estimated anchoring parameter for the 1985–1998 period. We view this case as quite pessimistic: expectations behave as they did before 1998, which means that all of the progress in anchoring expectations since then is lost.

### V.B. Deriving Inflation Paths

For given assumptions about the Beveridge curve and inflation expectations and a given path of the unemployment rate, and starting from actual data through September 2022, we construct a monthly simulation of the economy. For each month, the steps are:

- Use the Beveridge curve to derive $V/U$ given the assumed $U$, and compute the twelve-month average of $V/U$.
- Compute the twelve-month headline shock $H$ given zero monthly shocks starting in October 2022 and the actual shocks before that. The twelve-month average declines to zero in September 2023.
- Given the twelve-month $V/U$ and $H$, compute the core inflation gap from the monthly Phillips curve (column 4 of table 1).
- Given the core inflation gap and the level of expected inflation in the previous month, derive the current levels of core inflation and

29. If $v^*(u)$ and $v^{**}(u)$ are the pre-pandemic and pandemic Beveridge curves, then the curve in October 2022 is $.75v^{**}(u) + .25v^*(u)$. After October 2022, the curve in month $t$ is $v_t(u) = .75v_{t-1}(u) + .25v^*(u)$.

expected inflation from the equation for expected inflation (except in the most optimistic expectations scenario, in which expected inflation moves one-quarter of the way toward 2.2 percent).[30]

These steps yield a monthly series for core inflation starting in October 2022. By the assumption that future headline shocks are zero, the monthly path of headline inflation is the same. We aggregate over time to derive a twelve-month path of core inflation. The twelve-month path of headline inflation converges to core in September 2023.

### *V.C. Inflation Paths for the FOMC's Unemployment Forecasts*

In considering possible paths for unemployment, a natural starting point is the forecasts of Federal Reserve policymakers, which are reported in the *SEP*s released after every other FOMC meeting. The most recent *SEP* as this paper is written is the one for September 21, 2022. In these forecasts, the unemployment rate rises only modestly over time and peaks in late 2023 at 4.4 percent. This unemployment rate is low by historical standards and equals the CBO's current estimate of the natural rate. According to the *SEP*, the economy will experience low unemployment at the same time as inflation falls back to the Federal Reserve's target.

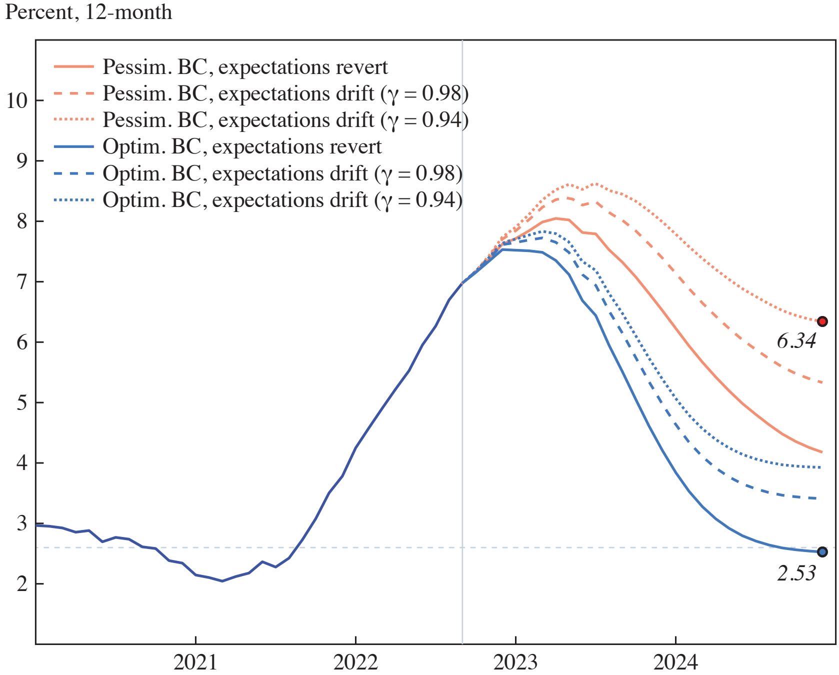
The *SEP* forecasts the unemployment rate in the fourth quarters of 2022, 2023, and 2024. We construct a monthly unemployment path by assigning each fourth quarter forecast to November and then interpolating, starting with the actual unemployment rate of 3.5 percent in September 2022.

Figure 17 shows simulated paths of twelve-month core (median CPI) inflation for the *SEP* unemployment path and our different Beveridge curve and expectations scenarios. Online appendix figure 17A repeats this exercise for median PCE inflation, yielding similar results. To illustrate the mechanisms behind the results, figure 18 shows the paths of all simulated variables for one case, the pessimistic Beveridge curve and intermediate expectations assumption.

The different core inflation paths in figure 17 have some common features. They all rise from the current level of 7 percent and peak at some point between December 2022 and July 2023, reflecting the fact that the twelve-month average of *V/U* continues to rise even as somewhat higher unemployment reduces the current *V/U*. Eventually core inflation starts to decline as *V/U* continues to fall and the pass-through effects of past headline shocks die out.

30. Except in the most optimistic scenario, we use the equations $\pi_t = \pi_t^e$ + core gap and $\pi_t^e = \gamma\pi_{t-1}^e + (1-\gamma)\,\pi_t$. Given the core gap and $\pi_{t-1}^e$, we can solve the two equations for $\pi_t$ and $\pi_t^e$.

**Figure 17.** Scenarios for Core CPI Inflation Conditional on September 2022 FOMC Unemployment Forecasts

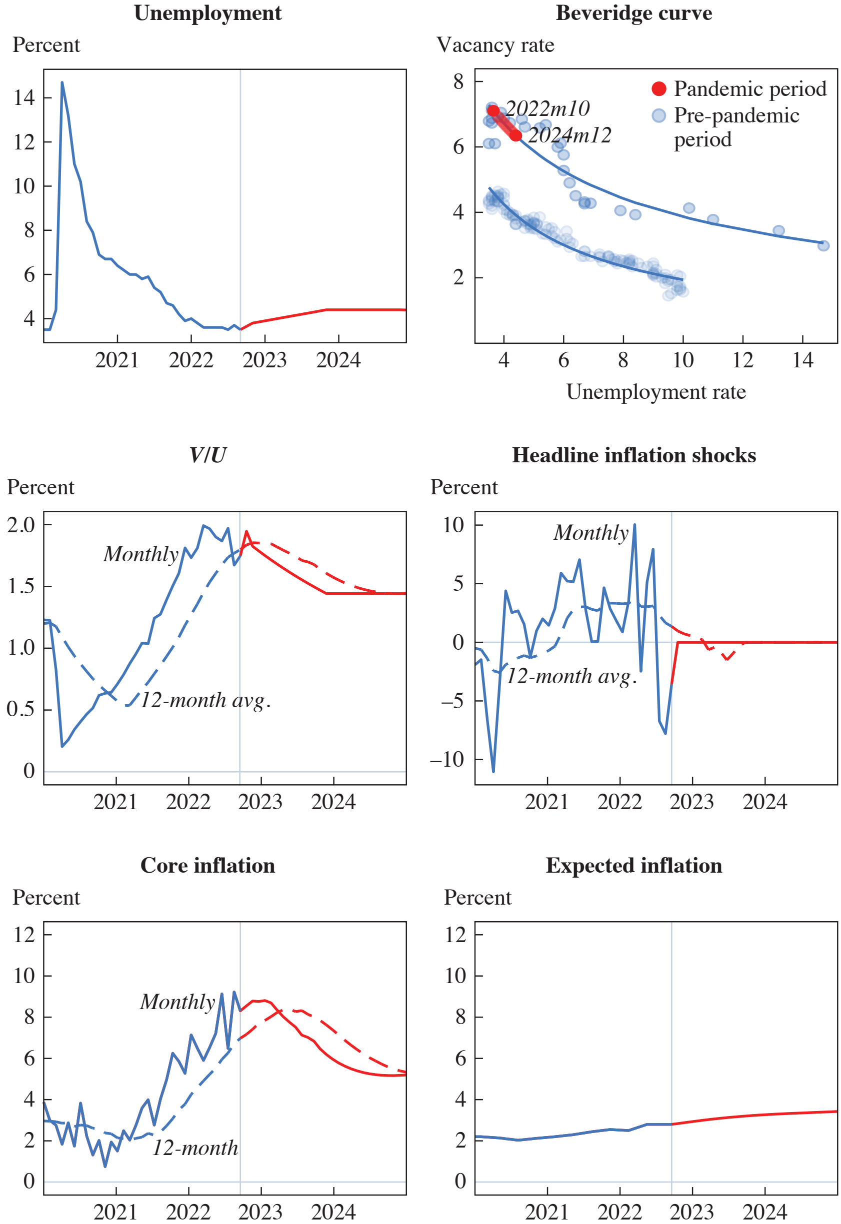



Sources: Authors' calculations; Federal Reserve Bank of Atlanta.
Note: Unemployment forecast from the *Summary of Economic Projections* of the Federal Open Market Committee (FOMC 2022), published in September 2022, which provides numbers for the fourth quarters of 2022, 2023, 2024, and 2025. We assign those forecasts to November of each year and interpolate a monthly unemployment series starting from the actual value of 3.5 percent in September 2022. The vertical line indicates September 2022. Core inflation denotes CPI median inflation. The horizontal dashed line shows the 2.6 percent target for median CPI based on the 2 percent PCE target as reported on the Federal Reserve Bank of Atlanta's Underlying Inflation Dashboard.

The levels of inflation, however, vary greatly across the different scenarios. With the most optimistic assumptions about both the Beveridge curve and expected inflation, core inflation peaks at 7.5 percent and falls to 2.5 percent in December 2024. With the most pessimistic assumptions, core inflation peaks at 8.6 percent and its December 2024 level is 6.3 percent, only 0.7 percentage points below the current level.

While both the Beveridge curve and inflation expectations affect the inflation path, the former is more important. If the Beveridge curve shifts back to its pre-pandemic position, the December 2024 inflation rate ranges from 2.5 to 3.9 percent depending on the expectations scenario. In contrast, if the

**Figure 18.** Scenario Conditional on September 2022 FOMC Unemployment Forecasts with Pessimistic Beveridge Curve and Drifting Expectations




Source: Authors' calculations.

Note: Figure reports scenario with COVID-19-era Beveridge curve and drifting expectations ($\gamma = 0.98$). Observations up to September 2022 are shown to the left of the vertical line; projections thereafter to the right. Core inflation denotes CPI median inflation.

Beveridge curve does not shift back, the inflation rate always stays above 4 percent. With the pandemic era Beveridge curve, a peak unemployment rate of 4.4 percent is not high enough to reduce *V/U* to a noninflationary level.

In interpreting these results, one nuance is that we forecast core inflation as measured by the weighted median CPI, whereas the Federal Reserve targets a 2 percent inflation rate in the PCE deflator. According to the Federal Reserve Bank of Atlanta's Underlying Inflation Dashboard, the Federal Reserve's target is equivalent to a 2.6 percent target for median CPI inflation, given the historical difference between the average levels of median CPI and headline PCE inflation. The upshot is that our most optimistic forecast for December 2024, a core inflation rate of 2.53 percent, is slightly below the Federal Reserve's target. In all the other scenarios, however, inflation stays above the target.

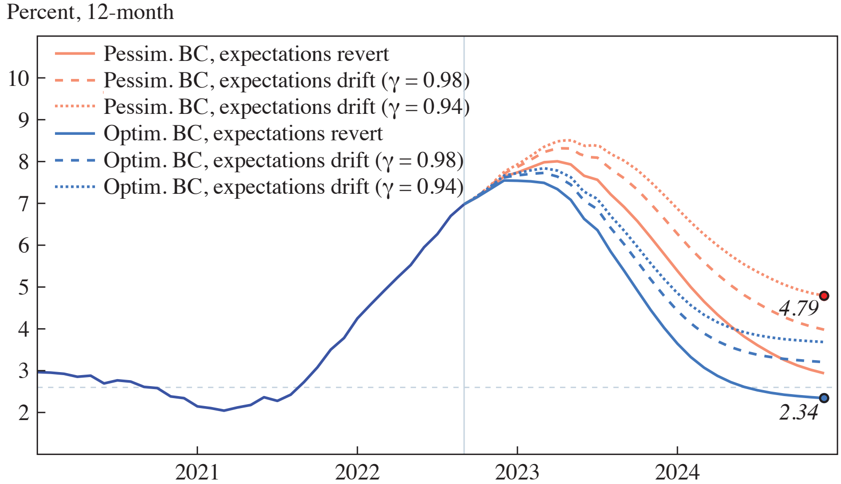
### V.D. Inflation Paths with Higher Unemployment

If the *SEP*'s unemployment path risks leaving inflation at a high level, how much higher must unemployment rise to more reliably meet the Federal Reserve's inflation goal? To shed light on this question, we consider two other unemployment paths. One is based on unemployment forecasts for the United States in the IMF's *World Economic Outlook* of October 2022. These forecasts are more pessimistic than the Federal Reserve's: the unemployment rate rises to 5.6 percent in the second half of 2024. We construct a monthly unemployment scenario by assigning the IMF's quarterly forecasts to the middle month of each quarter and interpolating. The other path is based on Summers's highly pessimistic suggestion that reversing the rise in inflation will require two years of 7.5 percent unemployment (Mellor 2022). In this scenario, we assume that the unemployment rate rises linearly from its September 2022 level to 7.5 percent in January 2023 and then stays at 7.5 percent through December 2024.

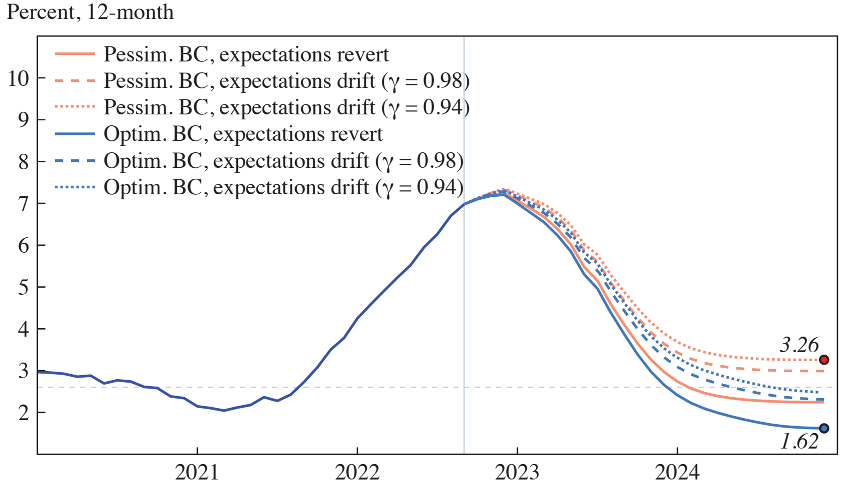
Figure 19, panel A, shows the inflation paths conditional on the IMF unemployment forecasts and our alternative Beveridge curve and expectations assumptions. As one would expect, higher unemployment lowers inflation: the December 2024 inflation level ranges from 2.3 to 4.8 percent, compared to 2.5 to 6.3 percent for the *SEP* unemployment path. Yet inflation still levels off above the Federal Reserve's target in most cases. Here, the behavior of inflation expectations is critical. Even with the more pessimistic Beveridge curve, median CPI inflation falls to 2.9 percent, only a bit above the implicit 2.6 percent target, if expected inflation reverts to its pre-pandemic level.

**Figure 19.** Scenarios for Core CPI Inflation Conditional on Alternative Unemployment Paths

**Panel A: Conditional on IMF staff unemployment path**




**Panel B: Conditional on higher unemployment path**




Sources: Authors' calculations; Federal Reserve Bank of Atlanta.

Note: Vertical line indicates September 2022. Core inflation denotes CPI median inflation. Panel A based on the IMF staff forecast for the quarterly path of unemployment underlying the October 2022 IMF *World Economic Outlook* report. Quarterly forecasts are allocated to the second month of each quarter, and a monthly path is obtained via interpolation. Panel B based on a higher unemployment path that assumes 7.5 percent unemployment during 2023 and 2024 as suggested by Summers (Mellor 2022). In this scenario, the unemployment rate rises linearly from its September 2022 level to 7.5 percent in January 2023 and remains at that level through December 2024. Horizontal dashes show 2.6 percent target for median CPI based on 2 percent PCE target reported on the Federal Reserve Bank of Atlanta's Underlying Inflation Dashboard.

Figure 19, panel B, shows the inflation paths for the scenario with two years of 7.5 percent unemployment. In this case, the differences across Beveridge curve and expectations assumptions are relatively small. The December 2024 inflation rates are clustered around 2.6 percent, with each less than 1 percentage point away from that level. Our analysis suggests, therefore, that this scenario's unemployment path robustly brings inflation close to the Federal Reserve's goal. Unfortunately, the cost is a painful and prolonged increase in unemployment. Moreover, a comparison of all the scenarios reported in figures 17–19 reveals that the sacrifice ratio, defined here as the additional unemployment required to reduce inflation by an extra percentage point by December 2024, is always larger for a greater reduction in inflation from the level today.

## VI. Conclusion

Yogi Berra observed that "it's tough to make predictions, especially about the future." This aphorism applies to the study of US inflation.

Looking backward, we can account fairly well for inflation behavior during the pandemic. A tight labor market has pushed up core inflation, headline inflation has deviated from core because of sharp rises in energy and auto prices and supply chain problems, and pass-through from these headline shocks has magnified the rise in core. All of these factors have been prominent in recent discussions of inflation. We contribute a simple framework in which we quantify their roles. We find that the combination of direct and pass-through effects from headline inflation shocks accounts for about 4.6 percentage points of the 6.9 percentage point rise in twelve-month inflation between the end of 2020 and September 2022. A rise in expected inflation accounts for 0.5 percentage points, and the rise in labor market tightness (measured by the ratio of vacancies to unemployment) accounts for 2 percentage points. The role of labor market tightness is rising over time.

Looking forward, we can forecast inflation if we specify the path of unemployment and the future behavior of the Beveridge curve and inflation expectations. There is much uncertainty about these factors, so it is difficult to make unconditional predictions. Yet we have one broad finding: the forecasts of Federal Reserve policymakers—that inflation will return to target while unemployment rises only to 4.4 percent—are reasonable only under quite optimistic assumptions about both the Beveridge curve and expectations. If the behavior of either proves less benign, then reducing inflation is likely to require higher unemployment than the Federal Reserve anticipates.

While our simple framework explains recent inflation fairly well, future research might improve it along many dimensions. For example, researchers should continue to refine the measurement of core inflation, of labor market tightness, and of inflation expectations. We should try to better understand the nonlinear effects of tightness and past headline shocks on core inflation. We also need more work on why the Beveridge curve shifts and why inflation expectations become anchored or de-anchored.

**ACKNOWLEDGMENTS** We are grateful to Philip Barrett, Olivier Blanchard, Marijn Bolhuis, Nigel Chalk, Judd Cramer, Benjamin Friedman, Jason Furman, Pierre-Olivier Gourinchas, N. Gregory Mankiw, Wilson Powell, Ayşegül Şahin, Antonio Spilimbergo, and James Stock for valuable comments. We thank Regis Barnichon for providing us with historical job openings data; Mattia Coppo, Yiyang Han, Nino Kodua, and Kyung Woong Koh for excellent research support; and Eduard Laurito and Gabi Ionescu for administrative support. All errors remaining are our own. The views expressed here are those of the authors and do not necessarily represent those of the IMF, its Management and Executive Board, or IMF policy.

## References

Abraham, Katharine, John Haltiwanger, and Lea Rendell. 2020. "How Tight Is the US Labor Market?" *Brookings Papers on Economic Activity*, Spring, 97–138.

Ball, Laurence, Daniel Leigh, Prachi Mishra, and Antonio Spilimbergo. 2021. "Measuring U.S. Core Inflation: The Stress Test of COVID-19." Working Paper 29609. Cambridge, Mass.: National Bureau of Economic Research. https://www.nber.org/papers/w29609.

Ball, Laurence, and N. Gregory Mankiw. 1994. "Asymmetric Price Adjustment and Economic Fluctuations." *Economic Journal* 104, no. 423: 247–61.

Ball, Laurence, and Sandeep Mazumder. 2011. "Inflation Dynamics and the Great Recession." *Brookings Papers on Economic Activity*, Spring, 337–81.

Ball, Laurence, and Sandeep Mazumder. 2018. "A Phillips Curve with Anchored Expectations and Short-Term Unemployment." *Journal of Money, Credit and Banking* 51, no. 1: 111–37.

Ball, Laurence, and Sandeep Mazumder. 2021. "A Phillips Curve for the Euro Area." *International Finance* 24, no. 1: 2–17.

Barnichon, Regis. 2010. "Building a Composite Help-Wanted Index." *Economics Letters* 109, no. 3: 175–78.

Barnichon, Regis, Luiz E. Oliveira, and Adam H. Shapiro. 2021. "Is the American Rescue Plan Taking Us Back to the '60s?" *FRBSF Economic Letter*, October 18. Federal Reserve Bank of San Francisco.

Barnichon, Regis, and Adam Hale Shapiro. 2022. "What's the Best Measure of Economic Slack?" *FRBSF Economic Letter*, February 22. Federal Reserve Bank of San Francisco.

Bernanke, Ben S. 2004. "The Great Moderation." Remarks made at the meetings of the Eastern Economic Association, Washington, DC, February 20.

Blanchard, Olivier. 2021. "In Defense of Concerns over the $1.9 Trillion Relief Plan." Blog post, Realtime Economics, Peterson Institute for International Economics, February 18. https://www.piie.com/blogs/realtime-economic-issues-watch/defense-concerns-over-19-trillion-relief-plan.

Blanchard, Olivier. 2022. "Why I Worry about Inflation, Interest Rates, and Unemployment." Blog post, Realtime Economics, Peterson Institute for International Economics, March 14. https://www.piie.com/blogs/realtime-economic-issues-watch/why-i-worry-about-inflation-interest-rates-and-unemployment.

Blanchard, Olivier, Alex Domash, and Lawrence H. Summers. 2022. "Bad News for the Fed from the Beveridge Space." Policy brief. Washington: Peterson Institute for International Economics. https://www.piie.com/publications/policy-briefs/bad-news-fed-beveridge-space.

Bolhuis, Marijn A., Judd N. L. Cramer, and Lawrence H. Summers. 2022. "Comparing Past and Present Inflation." Working Paper 30116. Cambridge, Mass.: National Bureau of Economic Research. https://www.nber.org/papers/w30116.

Borenstein, Severin, A. Colin Cameron, and Richard Gilbert. 1997. "Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes?" *Quarterly Journal of Economics* 112, no. 1: 305–39.

Briggs, Joseph. 2022. "The Beveridge Curve Debate: Has Match Efficiency Really Declined?" Goldman Sachs Economics Research, August 7, 2022.

Bryan, Michael F., and Stephen G. Cecchetti. 1994. "Measuring Core Inflation." In *Monetary Policy*, edited by N. Gregory Mankiw. Chicago: University of Chicago Press.

Crump, Richard K., Stefano Eusepi, Marc Giannoni, and Ayşegül Şahin. 2022. "The Unemployment-Inflation Trade-off Revisited: The Phillips Curve in COVID Times." Working Paper 29785. Cambridge, Mass.: National Bureau of Economic Research. https://www.nber.org/papers/w29785.

di Giovanni, Julian, Şebnem Kalemli-Özcan, Alvaro Silva, and Muhammed A. Yildirim. 2022. "Global Supply Chain Pressures, International Trade, and Inflation." Working Paper 30240. Cambridge, Mass.: National Bureau of Economic Research. https://www.nber.org/papers/w30240.

Dolmas, Jim. 2005. "Trimmed Mean PCE Inflation." Working Paper 0506. Federal Reserve Bank of Dallas Research Department. https://www.dallasfed.org/~/media/documents/research/papers/2005/wp0506.pdf.

Dolmas, Jim, and Evan F. Koenig. 2019. "Two Measures of Core Inflation: A Comparison." Federal Reserve Bank of St. Louis *Review* 101, no. 4: 245–58.

Domash, Alex, and Lawrence H. Summers. 2022. "How Tight Are U.S. Labor Markets?" Working Paper 29739. Cambridge, Mass.: National Bureau of Economic Research. https://www.nber.org/papers/w29739.

European Central Bank. 2014. "Indirect Effects of Oil Price Developments on Euro Area Inflation." *Monthly Bulletin*, December 2014, 54–56.

Faberman, R. Jason, Andreas I. Mueller, Ayşegül Şahin, and Giorgio Topa. 2020. "The Shadow Margins of Labor Market Slack." *Journal of Money, Credit and Banking* 52, no. S2: 355–91.

Federal Open Market Committee (FOMC). 2022. *Summary of Economic Projections*. Washington: Board of Governors of the Federal Reserve System. https://www.federalreserve.gov/monetarypolicy/files/fomcprojtabl20220921.pdf.

Figura, Andrew, and Chris Waller. 2022, "What Does the Beveridge Curve Tell Us about the Likelihood of a Soft Landing?" FEDS Notes. Washington: Board of Governors of the Federal Reserve System.

Friedman, Milton. 1968. "The Role of Monetary Policy." *American Economic Review* 58, no. 1: 1–17.

Furman, Jason. 2022. "America's Wage-Price Persistence Must Be Stopped." *Project Syndicate*, August 2. https://www.project-syndicate.org/commentary/inflation-wage-price-spiral-requires-fed-tightening-by-jason-furman-2022-08.

Furman, Jason, and Wilson Powell III. 2021. "What Is the Best Measure of Labor Market Tightness?" Blog post, Realtime Economics, Peterson Institute for International Economics, November 22. https://www.piie.com/blogs/realtime-economic-issues-watch/what-best-measure-labor-market-tightness.

Gagnon, Joseph E., and Christopher G. Collins. 2019. "Low Inflation Bends the Phillips Curve." Working Paper 19-6. Washington: Peterson Institute for International Economics. https://www.piie.com/publications/working-papers/low-inflation-bends-phillips-curve.

Gordon, Robert J. 1975. "Alternative Responses of Policy to External Supply Shocks." *Brookings Papers on Economic Activity*, no. 1: 183–206.

Hazell, Jonathon, Juan Herreño, Emi Nakamura, and Jón Steinsson. 2022. "The Slope of the Phillips Curve: Evidence from U.S. States." *Quarterly Journal of Economics* 137, no. 3: 1299–344.

Hilscher, Jens, Alon Raviv, and Ricardo Reis. 2022. "How Likely Is an Inflation Disaster?" Working Paper. Social Science Research Network, April 27. https://ssrn.com/abstract=4083404.

International Monetary Fund (IMF). 2022. *World Economic Outlooks: Countering the Cost-of-Living Crisis*. Washington: Author. https://www.imf.org/en/Publications/WEO/Issues/2022/10/11/world-economic-outlook-october-2022.

Krugman, Paul. 2021. "Wonking Out: I'm Still on Team Transitory." *New York Times*, September 10. https://www.nytimes.com/2021/09/10/opinion/transitory-inflation-covid-consumer-prices.html.

Medoff, James L., and Katherine G. Abraham. 1982. "Unemployment, Unsatisfied Demand for Labor, and Compensation Growth in the United States, 1956–1980." In *Workers, Jobs, and Inflation*, edited by Martin Baily. Washington: Brookings Institution.

Mellor, Sophie. 2022. "5 Years at 6% Unemployment or 1 year at 10%: That's What Larry Summers Says We'll Need to Defeat Inflation." *Fortune Magazine*, June 21.

Mortensen, Dale T., and Christopher Pissarides. 1999. "Job Reallocation, Employment Fluctuations and Unemployment." In *Handbook of Macroeconomics, Volume 1A*, edited by John B. Taylor and Michael Woodford. Amsterdam: North Holland.

Owyang, Michael T., and E. Katarina Vermann. 2014. "Rockets and Feathers: Why Don't Gasoline Prices Always Move in Sync with Oil Prices?" *Regional Economist*, Federal Reserve Bank of St. Louis, October 1.

Phillips, A. W. 1958. "The Relation between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861–1957." *Economica* 25, no. 100: 283–99.

Powell, Jerome. 2021a. "Oversight of the Treasury Department's and Federal Reserve's Pandemic Response." Testimony before the Financial Services Committee of the US House of Representatives, March 23.

Powell, Jerome. 2021b. "Opening Remarks: Monetary Policy in the Time of COVID." In *Economic Policy Symposium Proceedings: Macroeconomic Policy in an Uneven Economy*. Jackson Hole, Wyo.: Federal Reserve Bank of Kansas City.

Ramey, Valerie A., and Sarah Zubairy. 2018. "Government Spending Multipliers in Good Times and in Bad: Evidence from U.S. Historical Data." *Journal of Political Economy* 126, no. 2: 850–901.

Reis, Ricardo. 2021. "Losing the Inflation Anchor." *Brookings Papers on Economic Activity*, Fall, 307–61.

Seliski, John, Aaron Betz, Yiqun Gloria Chen, U. Devrim Demirel, Junghoon Lee, and Jaeger Nelson. 2020. "Key Methods That CBO Used to Estimate the Effects of Pandemic-Related Legislation on Output." Working Paper 2020-07.

Washington: Congressional Budget Office. https://www.cbo.gov/system/files/2020-10/56612-Key-Methods.pdf.

Spilimbergo, Antonio, Prachi Mishra, Gita Gopinath, Daniel Leigh, and Laurence Ball. 2021. "US Inflation: Set for Take-Off?" *VoxEU*. https://cepr.org/voxeu/columns/us-inflation-set-take.

Staiger, Douglas, James Stock, and Mark Watson. 1997. "How Precise Are Estimates of the Natural Rate of Unemployment?" In *Reducing Inflation: Motivation and Strategy*, edited by Christina Romer and David Romer. Chicago: University of Chicago Press.

Summers, Lawrence H. 2021. "The Biden Stimulus Is Admirably Ambitious. But It Brings Some Big Risks, Too." *Washington Post*, February 4.

Summers, Lawrence H., and Fareed Zakaria. 2022. "On GPS: Is a Recession Inevitable?" Interview, CNN, July 23, https://www.cnn.com/videos/tv/2022/07/23/exp-gps-0724-summers-on-whether-recession-is-inevitable.cnn; transcript https://transcripts.cnn.com/show/fzgps/date/2022-07-24/segment/01.

Verbrugge, Randal. 2021. "Is It Time to Reassess the Focal Role of Core PCE Inflation?" Working Paper 21–10. Federal Reserve Bank of Cleveland. https://www.clevelandfed.org/publications/working-paper/2021/wp-2110-time-to-reassess-focal-role-of-core-pce-inflation.

Yellen, Janet. 2019. "Former Fed Chair Janet Yellen on Why the Answer to the Inflation Puzzle Matters." Remark delivered at "What's (Not) Up with Inflation?" Washington: Hutchins Center on Fiscal and Monetary Policy, Brookings Institution, October 3.

# *Comments and Discussion*

COMMENT BY

**JASON FURMAN**[1] "Understanding US Inflation during the COVID-19 Era" by Laurence Ball, Daniel Leigh, and Prachi Mishra is among the scariest macroeconomic papers written in 2022. It diagnoses much of the increase in inflation in the United States as reflecting labor market tightness—and its model highlights the potential challenge of wringing this inflation out of the system. While I have some quibbles with particular parts of the analysis, overall I find it a reasonable quantification of the situation facing the US economy as a result of the enormous shock and extraordinary relief provided during the COVID-19 period.

This comment makes six points.

1. I HOPE THE PAPER IS WRONG Ball, Leigh, and Mishra's paper is a "choose your own adventure" that does not take a strong stance on the key parameters. Instead, the authors provide a forecast that is conditional on a trajectory for the unemployment rate and assumptions about a variety of the parameters.

The paper usefully focuses on two critical parameters. The first is shifts in the Beveridge curve. In the pandemic period the Beveridge curve has shifted out dramatically as shown in figure 14. As a result, even though the unemployment rate in mid-to-late 2022 was about 3.5 percent, as it was before the pandemic, the job openings rate was around 2 percentage points

1. I am indebted to Wilson Powell III for his usual outstanding research assistance on this comment.

higher.[2] As a result, the labor market was much tighter than it was prior to the pandemic, with about 1.7 job openings for every unemployed worker, up from a ratio of 1.2 prior to the pandemic.

The question is whether the Beveridge curve will shift back on its own, with reduced labor demand resulting in lower openings without rising unemployment. This is not something that has happened before (Blanchard, Domash, and Summers 2022), but then again neither have we seen such an abrupt and large shift out in the Beveridge curve.

The authors speculate about possible sources of this dramatic shift but neither they nor anyone else has a convincing story for why it has shifted so much. One possibility is a temporary response to the dramatic adjustments of the labor market during the pandemic period, for example, people finding new employers to satisfy their changed job preferences, such as for working from home. Under this possibility, once the labor market returns to normal the Beveridge curve would shift all the back to where it was before the pandemic.

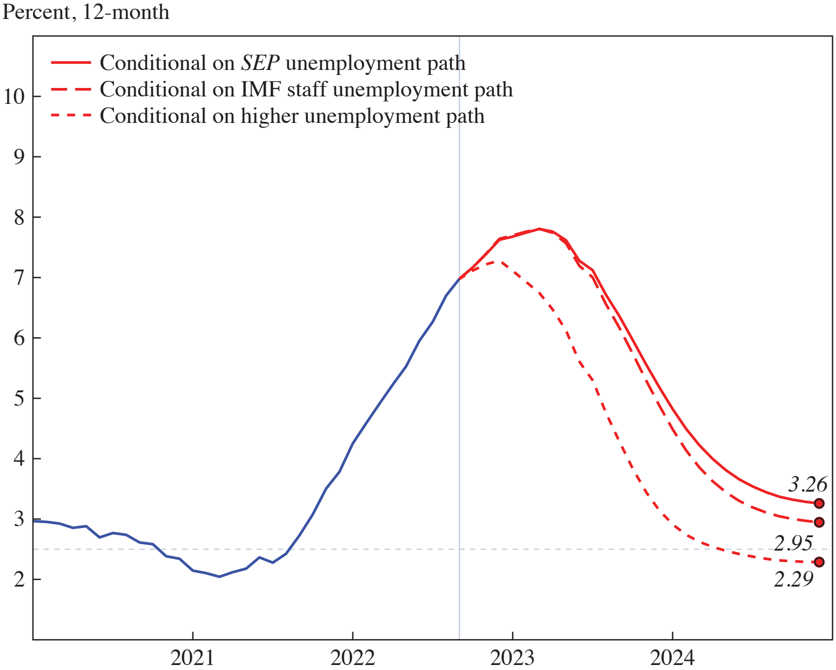
The fact that the Beveridge curve has shifted only a fraction of the way back in the year since COVID-19 became more normalized, expanded unemployment insurance expired, and schools reopened, however, suggests that it would not be reasonable to assume the Beveridge curve shifts all of the way back. In my scenarios I will assume, arbitrarily, that the Beveridge curve shifts two-thirds of the way back to where it was prior to the pandemic. This means some "immaculate" reduction in openings without a rise in the unemployment rate is possible, but that it would not return the economy all the way to where it was prior to the pandemic.

The second key issue is how inflation expectations evolve. The authors assume that long-run expectations update based on actual inflation. I assume that they are as anchored as they were prior to the pandemic ($\gamma = 0.991$ in the authors' model) but also that they exogenously shift halfway back to where they were pre-pandemic independent of the effect of actual inflation.

Finally, I follow the authors in assuming that going forward the headline shock is zero. In my comment at the conference in September, I assumed a cumulative −1 percentage point headline shock with headline Consumer Price Index (CPI) cumulatively lower than median inflation over the five remaining months of 2022. In the two months since the conference, this

2. Bureau of Labor Statistics, "Labor Force Statistics from the Current Population Survey (LNS14000000)," https://data.bls.gov/timeseries/LNS14000000; "Job Openings and Labor Turnover Survey (JTS000000000000000JOR)," https://data.bls.gov/timeseries/JTS000000000000000JOR.

**Figure 1.** Inflation Conditional on Different Unemployment Paths



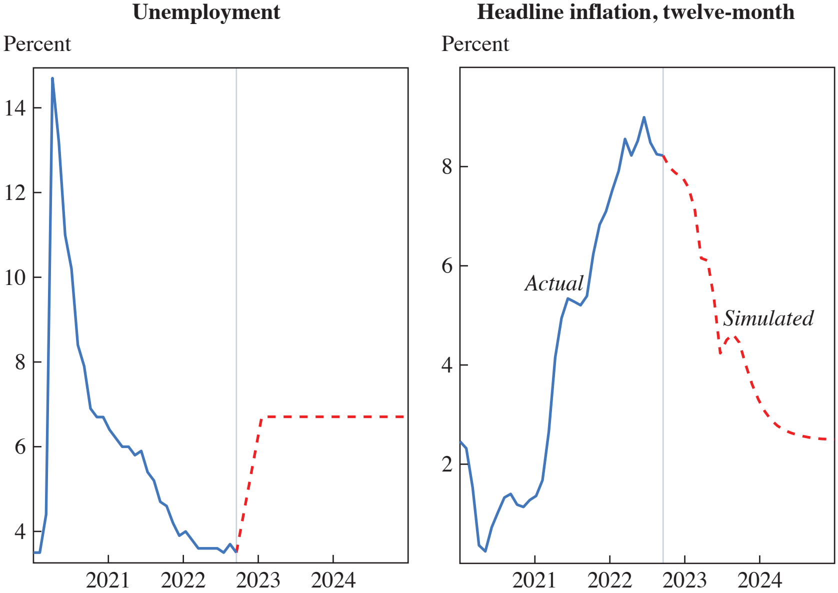

Source: Author's calculations.

entire shock has already happened. With this shock already incorporated into the updated data, I do not assume any further adjustment going forward.

The results of these assumptions are shown in figure 1. If unemployment follows the path in the September *Summary of Economic Projections* (*SEP*), maxing out at 4.4 percent in 2023, the median inflation rate would come down to 3.26 percent, equivalent to about 2.75 percent for the Federal Reserve's personal consumption expenditures (PCE) inflation target. If unemployment rises further to the 5.4 percent assumed by the International Monetary Fund (IMF) staff, inflation would only slightly exceed the Federal Reserve's target. Finally, if the unemployment rose to 7.5 percent for two straight years, as hypothesized by Lawrence Summers, inflation would fall slightly below the Federal Reserve's target by the end of 2024.

Overall to get inflation down the Federal Reserve's target under these assumptions would require the unemployment rate to be 6.7 percent for 2023 and 2024 as shown in figure 2.

**Figure 2.** Base Case for Unemployment Required to Hit the Federal Reserve's Inflation Target

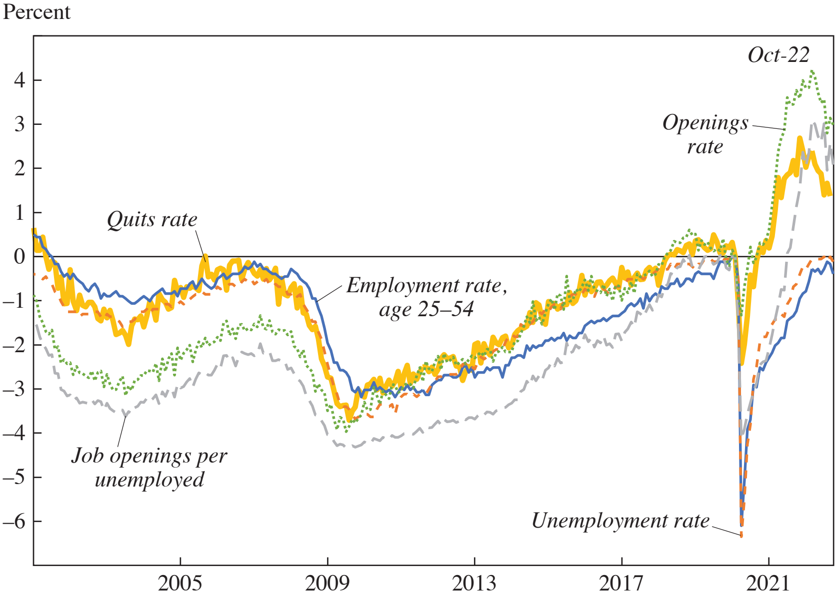



Source: Author's calculations.

2. *V/U* (OR *U/V*) IS AN IMPORTANT SLACK VARIABLE In recent years there has been an increased interest in a range of measures of labor market tightness that go beyond the unemployment rate. Two of the leading variables that have been advanced are quits and job openings (Furman and Powell 2021). There is a historical basis for this focus, but it came into strong relief over the last year because the unemployment rate was showing excess slack relative to the pre-pandemic labor market even while other measures like quits and openings showed a dramatically tighter labor market, as shown in figure 3, which normalizes a range of measures of labor market slack to zero prior to the pandemic with a standard deviation of one.

In theory, slack could be described as a function of the unemployment rate, the openings rate, and the quit rate, $f$ (unemployment rate, openings rate, quit rate). Or it could be a function of the difference between the unemployment rate and the non-accelerating inflation rate of unemployment (NAIRU) with a time-varying NAIRU that depends on shifts in the Beveridge curve: $f$ (unemployment rate – NAIRU [openings, quits]).

**Figure 3. Measures of Labor Market Tightness**




Sources: Bureau of Labor Statistics; Indeed Hiring Lab via Macrobond; author's calculations.

Note: Measures standardized using standard deviation from 2001 through 2018 and indexed to equal zero in February 2020. Prime-age employment is the share of the civilian population age 25–54 that is employed. Unemployment rate is the U-3 unemployment rate. The quits rate is quits divided by total nonfarm employment. The openings rate is openings divided by the sum of total nonfarm employment and openings. Job openings for October 2022 are estimated based on Indeed Hiring Lab job postings. The unemployment rate is plotted so that higher values correspond with a greater degree of labor market tightness, consistent with other measures.

The authors simplify all of this into a parsimonious single variable: slack = *f* (openings/unemployment) or $f(V/U)$.

Running a basic Phillips curve with different inflation concepts as the dependent variable $Inflation_{t \text{ to } t+4q} = \beta_0 + \beta_1 * Slack_t + \varepsilon_t$, the best predictor is actually the inverse of the authors' variable—the number of unemployed per job opening as shown in table 1. (Note that none of the slack variables are very good at explaining overall inflation which is very sensitive to exogenous shocks in energy and food prices.)

3. MEDIAN CPI IS THE RIGHT MEASURE OF INFLATION The authors argue, convincingly in my view, that median CPI is likely the right measure of inflation. In particular it has three desirable properties: (1) It is less volatile than core CPI. Over the last two years, for example, core CPI has been

**Table 1.** Adjusted $R^2$ in Phillips Curve Regressions for CPI

| | *Overall* | *Ex food and energy* | *Trimmed mean* | *Median* |
|---|---|---|---|---|
| Unemployed per job opening | –0.01 | 0.42 | 0.30 | 0.68 |
| Quits rate | 0.01 | 0.41 | 0.35 | 0.67 |
| Unemployment rate | –0.01 | 0.33 | 0.27 | 0.56 |
| Job openings per unemployed | –0.01 | 0.29 | 0.19 | 0.46 |
| Openings rate | –0.01 | 0.28 | 0.13 | 0.43 |
| Prime-age employment rate | 0.03 | 0.22 | 0.28 | 0.40 |

Sources: Bureau of Labor Statistics via Macrobond; author's calculations.

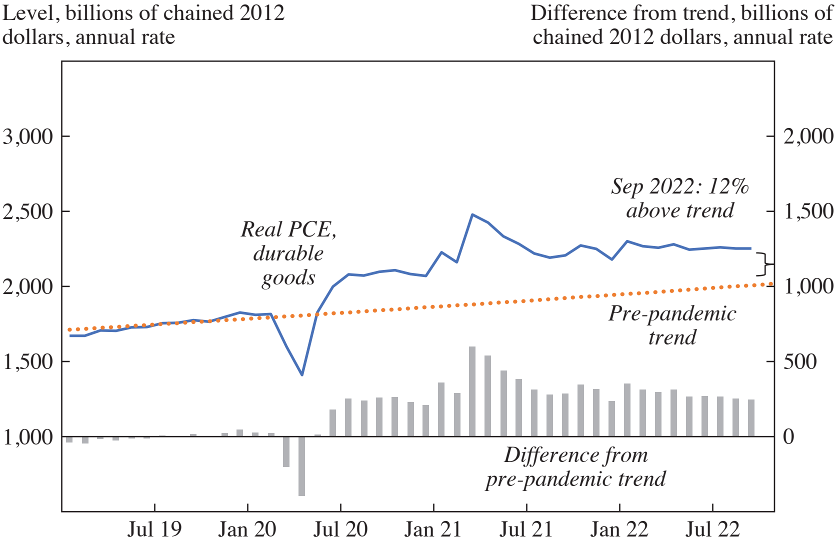
volatile as components like used cars have had outsized increases and decreases. By flexibly excluding outliers, median CPI is much less volatile. (2) It is a reasonable univariate predictor of future inflation. The median CPI provides as good, or perhaps a better, signal for future inflation as any other measure of underlying inflation. (3) Median CPI is much more predictable from labor market variables. Table 1 shows that *every* measure of labor market slack does a better job predicting median inflation than any other inflation concept. As such it appears to be effectively picking up "cyclically sensitive inflation" in the sense of Stock and Watson (2020).

The biggest criticism of the median CPI has been that shelter plays an outsized role in it.[3] The Federal Reserve Bank of Cleveland, which calculates the widely used median CPI, reduced the importance of shelter by dividing the component into four regions. Nevertheless, shelter in one of the regions is still the median category about half of the time. As the authors argue, it is not clear why this should bother us. Shelter is only the median item because half of the items (on a weighted basis) are above and below it. Moreover, the median of anything excluding the median is generally very close to the median assuming a smooth distribution. The fact that median CPI works so well empirically suggests these concerns are largely unfounded, although given the lags in the translation of spot rents to all rents, there is good reason to also keep an eye on other measures of underlying inflation.

4. HEADLINE SHOCKS REFLECT AN UNKNOWN COMBINATION OF SUPPLY AND DEMAND The authors develop a concept called "headline shocks" that is

3. Note that shelter is about one-third of the CPI but housing is only about one-sixth of the PCE price index. So this is a smaller issue for the median PCE. The paper, however, is focused on the median CPI. See Bureau of Labor Statistics, "Consumer Price Index," table 1 (2019–2020 Weights), "Relative Importance of Components in the Consumer Price Indexes: U.S. City Average, December 2021," https://www.bls.gov/cpi/tables/relative-importance/2021.htm.

**Figure 4.** Real Personal Consumption Expenditures, Durables



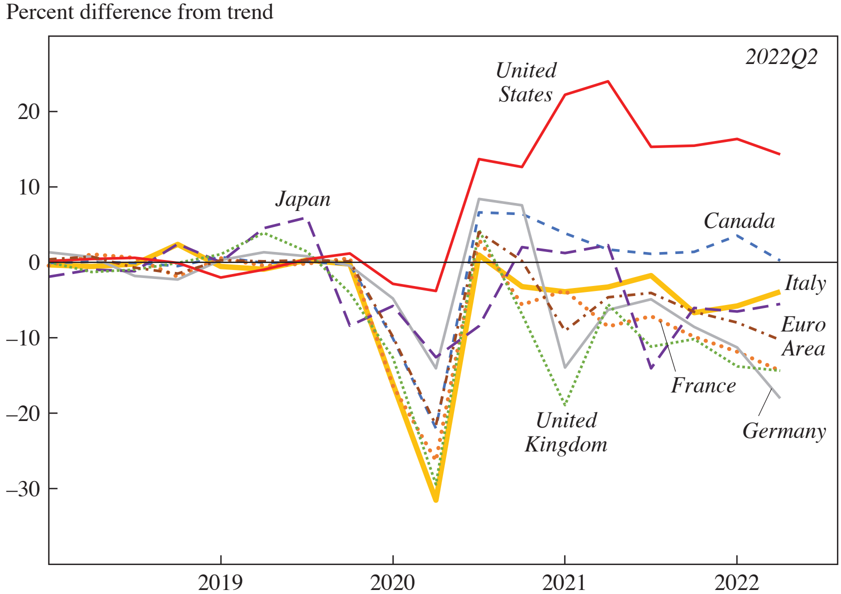

Sources: Bureau of Economic Analysis via Macrobond; author's calculations.
Note: Pre-pandemic trend based on log-linear regression for January 2018 to December 2019.

the difference between headline CPI and median CPI. Although they are agnostic about the interpretation of this headline shock, in general they lean into understanding it as a supply shock. This is problematic because unlike the difference between headline CPI and CPI excluding food and energy, this headline shock is really more about changes in the skewness of the CPI that are difficult to interpret.

Most of the measures the authors use to assess supply could just as easily be interpreted as demand. The Federal Reserve Bank of New York's Global Supply Chain Pressure Index, for example, records the difference between supply and demand—which is why it showed a rapid improvement in supply chains in the second half of 2008 when demand collapsed.

Consumption patterns skewed toward goods also appear to reflect demand as much if not more than supply. The big increase in consumer durables spending occurred when the economy and the service sector were rapidly reopening with the initially successful rollout of vaccines. As shown in figure 4, consumer durable spending was higher in June 2021 (when the economy was largely reopened) than it was in December 2020 (when the economy was much more closed). Moreover as shown in figure 5, goods spending soared in the United States in the face of massive fiscal stimulus

**Figure 5. Real Durable Goods Expenditure Relative to Trend**




Sources: Organisation for Economic Cooperation and Development via Macrobond; author's calculations.
Note: Pre-pandemic trend based on log-linear regression for 2018:Q1 to 2019:Q4. Euro area excludes Cyprus.

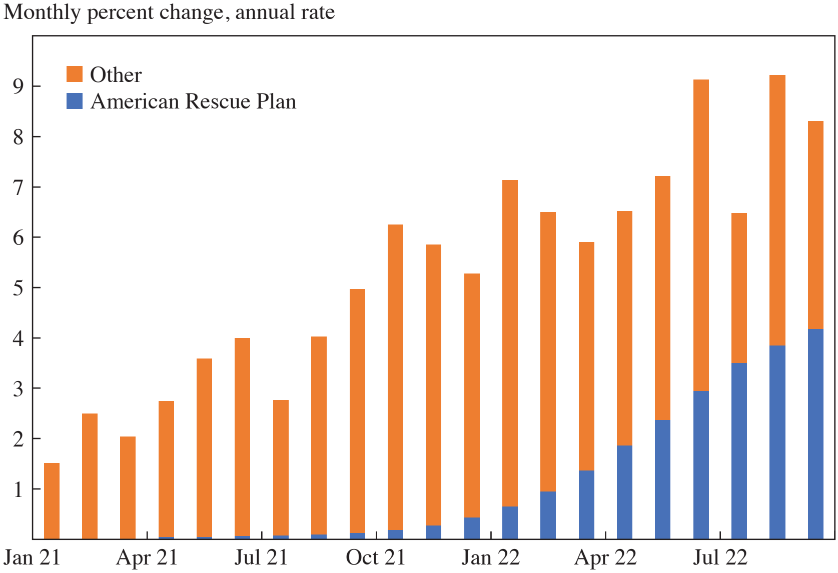
while not increasing above trend in other economies that were generally slower to reopen their service sectors.

5. THE PAPER MAY NEGLECT NONLINEARITIES AND TIMING EFFECTS FROM THE AMERICAN RESCUE PLAN The paper finds a relatively small effect of the American Rescue Plan on inflation in 2021 but a growing effect over the course of 2022 as shown in figure 6. This timing is the result of the lag structure assumed in their model: it takes some time for the American Rescue Plan to raise *V/U*, and then much of the effect that higher *V/U* has on inflation occurs over the following year. As a general matter this may be a reasonable lag structure, but for a massive change like the American Rescue Plan it is considerably less plausible that the effects were so small in 2021.

An alternative perspective on inflation, instead of modeling how stimulus affects the labor market and then how the labor market affects inflation, is to just go straight from the effect of stimulus on nominal GDP and then divide that impact into a price effect and an output effect (Furman 2022).

Specifically, using standard multipliers, output by 2021:Q3 would have been expected to be 4.8 percent above pre-pandemic estimates of potential.

**Figure 6.** Median CPI Inflation




Source: Author's calculations.

Moreover, pre-pandemic estimates of potential were unlikely to be a reasonable estimate of potential in 2021 because of reduced immigration, the time it takes to get people back into the labor force, forgone research and investment, and the lingering effects of other disruptions. To avoid inflation the economy would have needed to operate dramatically above potential in 2021. More realistically, the economy operated roughly at its potential with all of the additional nominal GDP showing up in the form of higher prices. This effect is much more immediate, occurring when the additional spending happened in 2021, not delayed to 2022 and operating through the labor market.

6. HOPE IS NOT A STRATEGY: IMPLICATIONS FOR MONETARY POLICY Finally, I would take three policy implications from the authors' model:

First, de-anchoring inflation expectations is costly. To the degree that acting more aggressively earlier keeps inflation expectations in check, that could lower the total cumulative jobs cost of achieving any given inflation goal. Specifically, table 2 shows what amount of unemployment would be needed in 2023 and 2024 (or the point years of added unemployment) to get the Federal Reserve's PCE inflation target down to 2 percent under various scenarios for expectations. To the degree that expectations are

**Table 2. Inflation Expectations**

| | *Unemployment in 2023 and 2024 needed for 2 percent PCE inflation* | *Point years of added unemployment* |
|---|---|---|
| $\gamma = 0.90$ | 9.0 | 11.3 |
| $\gamma = 0.945$ (1985 – 1998) | 8.5 | 10.1 |
| $\gamma = 0.991$ (2009 – 2019) | 7.7 | 8.5 |
| $\gamma = 0.991$ + 0.3 pp exogenous reduction | 6.7 | 6.4 |
| Revert to 2.2 | 4.9 | 2.5 |

Source: Author's calculations.

**Table 3. Unemployment Increases Required for Different Inflation Targets**

| *PCE inflation at end of 2024* | *Unemployment in 2023 and 2024* | *Point years of added unemployment* | *Sacrifice ratio* |
|---|---|---|---|
| 2.0 | 6.7 | 6.4 | |
| | | | 8.5 |
| 2.5 | 4.7 | 2.1 | |
| | | | 2.5 |
| 3.0 | 4.1 | 0.9 | |
| | | | 1.0 |
| 3.5 | 3.9 | 0.4 | |
| | | | 0.6 |
| 4.0 | 3.7 | 0.1 | |

Source: Author's calculations.

less anchored (as they were in the past) or do not exogenously decline above and beyond learning from actual lower inflation, the result is a much higher unemployment rate needed to control inflation—possibly as high as 9 percent.

Second, there is likely no way to get inflation down without at least a period of higher unemployment, likely above 4.5 percent—which would correspond to a recession. It takes special edge-case assumptions, like a full return of the Beveridge curve to its pre-pandemic relationship, for this to happen.

Third, the cost of lowering inflation is nonlinear and is much higher to lower inflation from 3 percent to 2 percent than it is to lower inflation from 4 percent to 3 percent as shown in table 3. This might complement other, longer-term reasons why a higher inflation target might be desirable. Of course, it is very tricky for the Federal Reserve to try to keep inflation expectations anchored if there is any reality to or perception of its shifting to a higher inflation target. Achieving a higher inflation target might be politically and practically impossible, but this analysis increases the desirability of achieving it.

Overall the paper makes an important contribution to both our understanding of the sources of inflation in the pandemic period as well as helping to guide us out of it—while giving us some key metrics to look at to understand inflation and its sources in the future.

### REFERENCES FOR THE FURMAN COMMENT

Blanchard, Olivier, Alex Domash, and Lawrence H. Summers. 2022. "Bad News for the Fed from the Beveridge Space." Policy brief. Washington: Peterson Institute for International Economics. https://www.piie.com/publications/policy-briefs/bad-news-fed-beveridge-space.

Furman, Jason. 2022. "Why Did (Almost) No One See the Inflation Coming?" *Intereconomics* 57, no. 2: 79–86.

Furman, Jason, and Wilson Powell III. 2021. "What Is the Best Measure of Labor Market Tightness?" Blog post, Realtime Economics, Peterson Institute for International Economics, November 22. https://www.piie.com/blogs/realtime-economic-issues-watch/what-best-measure-labor-market-tightness.

Stock, James H., and Mark W. Watson. 2020. "Slack and Cyclically Sensitive Inflation." *Journal of Money, Credit and Banking* 52, no. S2: 393–428.

COMMENT BY

**AYŞEGÜL ŞAHIN** The COVID-19 pandemic which started in early 2020 resulted in a deep but brief recession. The unemployment rate rose from 3.5 percent to 14.7 percent from February 2020 to April 2020.[1] After the drastic drop in economic activity, the economy rebounded, and inflation, which had been dormant for two decades, flared up briskly with the core Consumer Price Index (CPI) inflation rising from 1.4 percent in January 2021 to 6 percent in January 2022.[2] This rapid rise in inflation initially was attributed to mostly transitory factors such as the shift in the composition of consumption from services to goods and supply chain disruptions reflecting pandemic-related factors. However, inflation turned out to be more persistent than initially assumed with the core CPI inflation still printing at 6.6 percent as of September 2022.

In this timely piece, Ball, Leigh, and Mishra examine the drivers of this recent surge in inflation and present projections for the medium-term

1. Bureau of Labor Statistics, "Labor Force Statistics from the Current Population Survey (LNS14000000)," https://data.bls.gov/timeseries/LNS14000000.

2. Bureau of Labor Statistics, "CPI for All Urban Consumers: All Items Less Food and Energy in U.S. City Average, 12-Month Percent Change (CUUR0000SA0L1E)," https://data.bls.gov/timeseries/CUUR0000SA0L1Es.

inflation outlook. They find that the rapid tightening of the labor market and the pass-through of past shocks to headline inflation to core inflation account for the run-up in inflation. They relate the headline shocks—defined as the difference between the total and core inflation—to increases in energy prices and backlogs of orders for goods and services. Lastly, the authors simulate the future path of inflation for alternative paths of the unemployment rate and argue that inflation is likely to remain above the Federal Reserve's inflation target unless unemployment rises by more than the Federal Reserve projects.

The reemergence of inflation after two decades of muted price increases is one of the key macroeconomic problems that we are facing as we approach the end of 2022. The Federal Reserve has been on a rapid tightening cycle, not seen since the early 1980s, to curb inflation and bring it back to its mandate-consistent level. With inflation remaining persistently high despite the 3 percentage points rise in the federal funds effective rate between March and November 2022, inflation will be our main focus of attention for years to come. Against this backdrop, the authors provide a detailed account of drivers of inflation and discuss the challenges we likely face going forward. This comment reviews and interprets the authors' findings and suggests new directions for research.

FRAMEWORK Ball, Leigh, and Mishra develop a multistep regression framework to decompose the surge in inflation and use their framework to provide projections under different assumptions. The multistep regression framework helps to introduce different potential drivers of high inflation despite not providing a clear decomposition between supply and demand factors.

It is useful to first review the regression framework to facilitate the interpretation of the findings and discuss their robustness. The paper starts with a simple, commonly used decomposition of observed inflation:

$$\pi_t = \pi_t^C + \pi_t^H, \tag{1}$$

where $\pi_t$ is headline inflation, $\pi_t^C$ is core inflation, and $\pi_t^H$ is the deviation between headline and core inflation. It is important to note that while the authors refer to $\pi_t^H$ as headline shocks, it represents the deviation between headline and core inflation and cannot be interpreted as an exogenous shock.

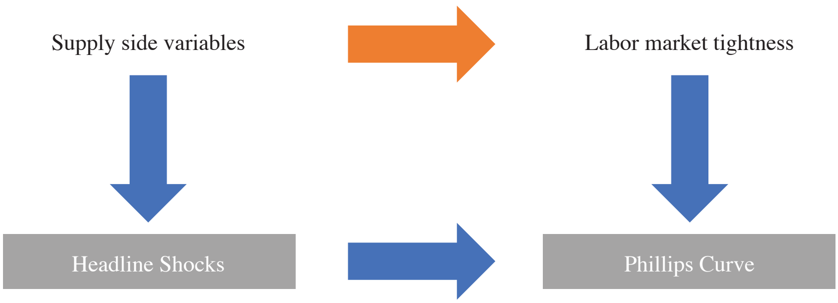
*Step 1: Phillips curve regression.* The first step is to run a Phillips curve–style regression which links core inflation to expected inflation, vacancy-to-unemployment ratio ($V/U$), and headline inflation shocks as well as quadratic and cubic terms. Specifically, the authors choose the following specification:

$$\pi_t^C - \pi_t^* = c + \underbrace{K_1 \frac{V_t}{U_t} + K_2 \left(\frac{V_t}{U_t}\right)^2 + K_3 \left(\frac{V_t}{U_t}\right)^3}_{\textit{market tightness}} + \underbrace{\eta_1 \pi_t^H + \eta_2 \left(\pi_t^H\right)^2 + \eta_3 \left(\pi_t^H\right)^3}_{\textit{headline shocks}} \tag{2}$$

where $\pi_t^*$ is the expected inflation; $\frac{V_t}{U_t}$ is vacancy-to-unemployment ratio, often referred to as labor market tightness; and $\pi_t^H$ is headline inflation shocks. For core inflation, the authors use the median CPI inflation rate published by the Federal Reserve Bank of Cleveland and use the Society of Professional Forecasters ten-year-ahead inflation expectations as a measure of $\pi_t^*$. Since the Job Openings and Labor Turnover Survey (JOLTS) starts only in 2000, the authors use the vacancy measures developed by Barnichon (2010), which combine the help wanted index with the JOLTS to construct a longer time series for vacancies. The authors capture the core inflation gap (median minus expected inflation) with four-quarter or twelve-month averages of *V/U* and headline shocks. The analysis focuses on the 1985–2022:Q3 period and does not use the data before 1985. This step picks up the co-movement between market tightness measures and inflation. In addition, the headline shocks, which are larger when the headline inflation deviates more from core inflation, could affect the core inflation gap.

*Step 2: headline inflation regressions.* The second step in analyzing inflation fluctuations is to interpret the deviation between headline and core inflation as headline inflation shocks and relate them to the recent developments in the macroeconomy. While the authors refer to the difference between headline and core inflation as headline inflation shocks, they do not specifically identify these shocks. Instead, in the second step of their regression framework they identify some variables that correlate with these deviations. They argue that shifts in either industry supply or industry demand could affect the headline inflation but do not attempt to decompose these into supply and demand channels. Instead, they find that changes in energy prices, backlogs of orders for goods and services, and changes in auto-related prices are positively related to headline inflation shocks. Clearly, these variables are endogenous to shifts in demand, shifts in composition of demand, and labor supply constraints.

**Figure 1.** Simple Diagram of the Multi-regression Framework




Source: Author's compilation.

*Step 3: decomposing the surge in inflation.* Equipped with two multivariate regressions, the authors then use the two reduced-form relationships consecutively to decompose the 6.9 percentage point rise in headline inflation, from 1.3 percent in December 2020 to 8.2 percent in September 2022. In particular, they first determine the contributions to the rise in inflation of higher expected inflation, higher levels of the vacancy-to-unemployment ratio, and headline shocks. Then they use the headline inflation regression to determine the shares of headline shocks attributed to energy price shocks, backlogs, and auto price shocks. They find that the direct and pass-through effects of headline inflation shocks account for about 4.6 percentage points of the 6.9 percentage point rise in twelve-month inflation. Most of this 4.6 percentage point total reflects energy price shocks and backlogs of work, with total contributions of 2.7 and 1.7 percentage points, respectively. The contribution of the vacancy-to-unemployment ratio to the rise in twelve-month inflation is 2 percentage points, nearly a third of the total inflation increase. A rise in expected inflation accounts for 0.5 percentage points. One caveat is that while market tightness does not seem to be the major factor in accounting for the rise in inflation, its importance seems to be rising over time. The results are shown in the authors' figure 12.

IS THE MULTISTEP MULTI-REGRESSION APPROACH REASONABLE? The appeal of the multi-regression framework is its simplicity. It helps connect each driver to core inflation either through the Phillips curve regression or through its direct or indirect effect through headline inflation shocks. Figure 1 shows how the multi-regression framework isolates the role of headline shocks by assuming that labor market tightness is not affected by those shocks. This assumption allows the authors to run repeated regressions and decompose the role of headline shocks and market tightness separately. However, it is likely that headline shocks had direct effects on the labor market, making it harder to interpret the decomposition. However, empirical evidence suggests that supply chain disruptions that the authors interpret as headline shocks had effects on the labor market. Amiti and others (forthcoming) document a big rise in imported input prices in the 2020:Q2–2022:Q1 period which coincided with a stark rise in wages. Import prices (excluding petroleum) increased by 6.7 percent during this period while the Employment Cost Index (ECI) increased by 4.1 percent. This is in contrast to the 2009:Q4–2019:Q3 period when the change in import prices was negligible and the ECI grew by 2.2 percent. They argue that, in normal times, firms can substitute between labor and imported intermediate inputs, thus cushioning any cost shock due to one of the two factors. This substitution mechanism has been highlighted by Feenstra and others (2018) and Elsby, Hobijn, and Şahin (2013). When labor costs go up, firms can outsource production to other countries and import intermediate inputs.

Over the past decades, US inflation has become more closely linked to global factors, as foreign competition and firms' ability to outsource have weakened the link between wage pressures and prices in the United States, as argued by Forbes (2019) and Obstfeld (2020). However, this substitution channel was less operational in the post-COVID-19 economy due to the large and simultaneous inflationary shocks to both labor and intermediate inputs. Moreover, US firms become less concerned about losing market share to foreign competitors when the shock is global in nature, raising their pass-through of cost shocks into prices. Amiti and others (forthcoming) use weekly earnings from the Quarterly Census of Employment and Wages (QCEW) for six-digit North American Industry Classification System (NAICS) industries in 2013–2021 and the Producer Price Index (PPI) for 527 six-digit NAICS industries and show that rising input prices are associated with increasing wages across industries, especially in 2021. They find that about one-third of the uptick in wage inflation can be attributed to the supply chain problems. In addition, they show in more detail that rising import prices triggered a shift away from imported intermediaries to domestic labor and wages and employment. This substitution channel suggests that headline shocks that the authors identify likely have affected the labor market and their true contribution on inflation is likely to be larger through their effects on labor market tightness. This orthogonality assumption is also important for the projections in the paper. Since market tightness is affected by headline shocks, when their effects subside, there should be a direct negative effect on market tightness as well.

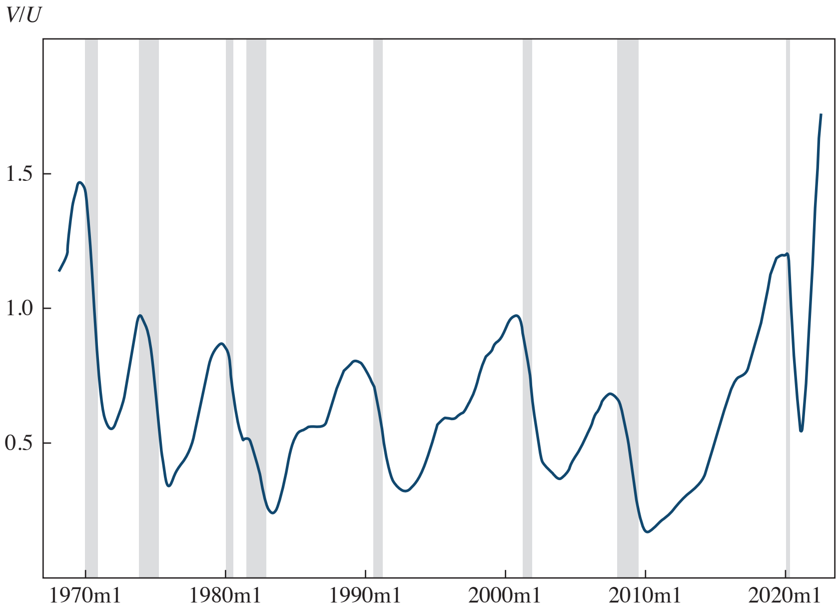
INTUITION FOR HIGHER-ORDER TERMS Another concern I have is the use of quadratic and cubic terms in the Phillips curve regressions which seem to capture the recent inflation behavior well. Paradoxically, there is little evidence of nonlinearity for wage inflation, especially when the authors include the pandemic period in their sample. I find these results hard to interpret. These higher-order terms seem significant and quantitatively important for price inflation, but the authors do not provide an economic explanation for why they would matter so much. The mechanism behind this nonlinearity remains unexplored but is vital for inflation projections. For example, the authors' figure 10 shows the wage inflation and price inflation gaps as a function of vacancy-to-unemployment ratio. In contrast to the results for price inflation, the estimated effect of market tightness on wage inflation is approximately linear. This disconnect between wage and price inflation makes the importance of higher-order terms of *V/U* on price inflation more puzzling since they do not seem to originate from wage pressures.

Since the paper's preferred measure of labor market slack is the vacancy-to-unemployment ratio, connection to the vast search and matching theory can help provide some intuition. For example, a recent literature argues that job-to-job transitions capture wage pressures better than the unemployment-to-employment transition rate by analyzing the predictive power of the unemployment rate, the unemployment-to-employment transition rate, hires from nonparticipation, and job-to-job transitions (Faberman and Justiniano 2015; Faccini and Melosi 2021; Karahan and others 2017; Moscarini and Postel-Vinay 2017, 2022). These papers argue that behavior of wages is better captured by job-to-job transitions than the unemployment rate. Since job-to-job transitions constitute a higher fraction of hires during tight labor markets, they might create the type of nonlinearities the authors identify. The underlying reasons for the nonlinearity remain an open and important issue for future research.

IS VACANCY-TO-UNEMPLOYMENT A PANACEA FOR THE PHILLIPS CURVE? That economists have long been pursuing the perfect measure of slack and emphasis on labor market tightness is nothing new. For example, George Perry, in one of the first Brookings papers, wrote: "For instance, many (including myself) argue that what matters is the difference between available jobs and available employees to fill those jobs" (1970, 412).

I like that the authors use the vacancy-to-unemployment ratio as the measure of labor market tightness, but using tightness alone does not solve the trend and compositional issues that other measures of slack are criticized for. This is clear in the historical time series of the vacancy-to-unemployment ratio plotted in figure 2. The vacancy-to-unemployment ratio averaged

**Figure 2.** Historical Evolution of Vacancy-to-Unemployment Ratio




Sources: Author's calculations; Bureau of Labor Statistics JOLTS.

at 0.70 in 1970–1979. In this period the core CPI inflation increased by 5.1 percentage points. In the January 2021 to September 2022 period, the vacancy-to-unemployment ratio averaged 1.06 and the core CPI inflation increased by 5.2 percentage points. Interestingly, during the Great Recession, which was characterized by subdued inflation, the US labor market was tighter than in the 1970s according to the measure used in the paper. The authors also show that their Phillips curve regression does not fit the 1970s well. Even the use of higher-order terms of *V/U* in the Phillips curve regressions does not capture the evolution of price inflation in the 1970s.

One potential problem about the vacancy series is that historical data and post-2000 data come from different data sources. The historical help wanted series and the more recent JOLTS data are very different, which makes it harder to interpret the level of *V/U* over time. But this disconnect in the historical data applies to observations between 1985 and 2000 as well. The second issue is the change in trend unemployment over time. Unemployment has trended down since the 1980s and measures of the natural rate of unemployment or NAIRU take this trend change into account to estimate cyclical changes in the unemployment rate. Using *V/U* alone without considering the changes in trend unemployment naturally inherits the same issues one encounters when using the unemployment rate as a measure of slack. Lastly, Abraham, Haltiwanger, and Rendell (2020) developed a generalized measure of labor market tightness which takes into account intensive and extensive margins of search activity on both demand and supply sides of the labor market and show that their measure captures the hiring process in the US economy better than the standard measure of labor market tightness. Their measure could potentially help explain why the fit is so bad for the 1970s.

Unfortunately, the authors do not investigate the economic mechanisms and measurement issues that might account for this poor fit, ignoring the 1970s in their analysis and only using post-1985 data. This choice, of course, comes at the expense of ignoring the only other high-inflationary episode in the last fifty years.

THE BEVERIDGE CURVE AND THE ROLE OF JOB LOSS IN A SOFT VS. HARD LANDING Inflation projections in the paper are based on a log-linear relationship between tightness and unemployment in the form of

$$\frac{V}{U} = aU^{b-1}. \tag{3}$$

The authors estimate this functional form with pre-pandemic data on unemployment and vacancies which they refer to as the pre-pandemic Beveridge curve. Then they focus only on the April 2020–August 2022 data and estimate a post-pandemic Beveridge curve. They rely on these estimates to convert the unemployment projections to $V/U$ with and without shifts in the Beveridge curve. The crucial assumption for this approach is that there is a one-to-one mapping between the unemployment rate and tightness. This assumption ignores the accounting identity that captures the evolution of unemployment which implies:

$$U_{t+1} = s_t\left(1 - U_t\right) - f_t U_t, \tag{4}$$

where $s_t$ is the inflow rate to unemployment and $f_t$ is the outflow rate from unemployment.

Search and matching frictions are typically summarized by the matching function of the Cobb–Douglas form which links hires to unemployment $U$ and vacancies $V$:

$$f = \frac{Hires}{U} = \frac{M\left(V, U\right)}{U} = A\left(\frac{V}{U}\right)^{\sigma}, \tag{5}$$

where $A$ is the matching efficiency and $\sigma$ is the elasticity of the matching function. The search and matching literature typically estimates the matching function using data on hires or job-finding rate, vacancies, and unemployment. Instead, the authors choose a functional form which makes it harder to compare their estimates with those in the literature. The flow steady state implies a Beveridge curve of the form:

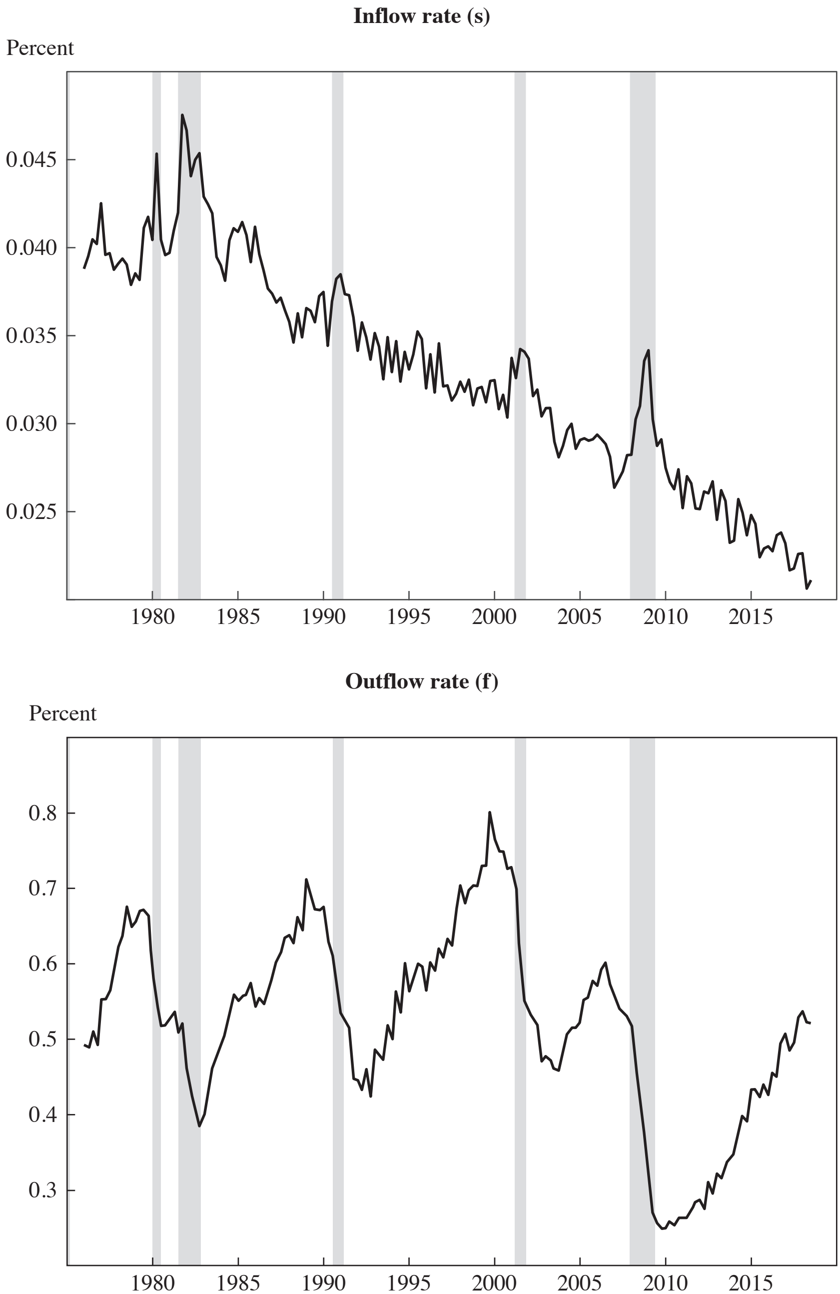
$$u = \frac{s}{s+f} = \frac{s}{s + A\left(\frac{V}{U}\right)^{\sigma}}, \tag{6}$$

as shown by Pissarides (1985). The implication of equation (6) is that the position of the Beveridge curve depends on the unemployment inflow rate, $s$. Increases in the inflow rate, which is associated with increases in layoffs and job destruction, shift the Beveridge curve out, implying a higher unemployment rate for the same level of vacancies. On the contrary, soft landings are associated with small increases in unemployment inflows. Figure 3 shows that the inflow rate increased sharply at the onset of deep recessions while it exhibited a muted response during mild recessions, such as the 1991–1992 and 2001 recessions which are interpreted as soft landings. On the contrary, the behavior of the outflow rate is very similar regardless of the severity of recessions. More importantly, contractionary monetary policy shocks tend to affect the unemployment inflow rate first. While the soft versus hard landing discussions in the paper focus on only one determinant of the Beveridge curve, $V/U$, the inflow rate is likely to be important in the near future.

CONCLUDING REMARKS Ball, Leigh, and Mishra provide a detailed account of inflation developments in the post-pandemic economy. They consider many different drivers of inflation and identify various interesting patterns. While this is a useful exercise to identify important channels, relying on a multi-regression framework likely would make the results less relevant as the economy goes through a new boom-bust cycle in the future. I am especially concerned about using different labor market indicators to explain different inflationary or disinflationary episodes as in the case of short-term unemployment to account for the inflation dynamics after the Great Recession. My preferred measure of labor market has been the unemployment rate.

In my view, a useful construct to gauge the unemployment-inflation trade-off is the so-called natural rate of unemployment, which is defined

**Figure 3. Historical Evolution of Unemployment Inflow and Outflow Rates**




Source: Author's calculations using data from Crump and others (2022).

as the unemployment rate such that, controlling for supply shocks, inflation remains stable. The natural rate of unemployment is affected by both business cycle fluctuations and secular factors. Furthermore, the unemployment-inflation trade-off is linked by the classical determinants of inflation, such as inflation expectations. To accommodate all of these facets, a comprehensive framework is required that uses a New Keynesian Phillips curve as well as detailed information on unemployment flows such as in Crump and others (2022). In this model, the natural rate is informed by wage and price inflation, inflation expectations, and changing secular factors. This micro-macro Phillips curve framework not only creates a clear link between the labor market and inflation, it also directly incorporates the movements in survey-based inflation expectations. A New Keynesian Phillips curve estimated with rich labor market data captures the joint behavior of unemployment, wage and price inflation, and inflation expectations in the 1960–2022 period very well with a time-invariant slope—estimated to be quite flat. Even if the slope of the Phillips curve is small in a forward-looking model, this does not necessarily imply a weak link between the unemployment gap and inflation. According to the micro-macro Phillips curve in Crump and others (2022), the natural rate of unemployment was around 5 percent before the onset of the pandemic and increased to 7 percent by mid-2022. This pronounced rise was primarily informed by strong wage growth rather than changes in inflation expectations. The model-based forecasts in Crump and others (2022) suggest that strong wage growth is likely to moderate only sluggishly, continuing to put upward pressure on inflation in the medium run. The model forecasts the unemployment rate to rise to around 5 percent by mid-2024 and the unemployment gap to narrow, bringing underlying inflation to around 2.8 percentage points—about 0.5 percentage points above its long-run trend. While episode-specific analysis could give helpful hints about recent developments in inflation, a model-based approach is likely to provide more enduring insights into determinants of inflation.

## REFERENCES FOR THE ŞAHIN COMMENT

Abraham, Katharine, John Haltiwanger, and Lea Rendell. 2020. "How Tight Is the US Labor Market?" *Brookings Papers on Economic Activity*, Spring, 97–165.

Amiti, Mary, Sebastian Heise, Fatih Karahan, and Ayşegül Şahin. Forthcoming. "Inflation Strikes Back: The Role of Import Competition and the Labor Market." *NBER Macroeconomics Annual*.

Barnichon, Regis. 2010. "Building a Composite Help-Wanted Index." *Economics Letters* 109, no. 3: 175–78.

Crump, Richard K., Stefano Eusepi, Marc Giannoni, and Ayşegül Şahin. 2022. "The Unemployment-Inflation Trade-off Revisited: The Phillips Curve in COVID Times." Working Paper. https://www.dropbox.com/s/24osn6dp5dnrfgw/CEGS_Update_20221001.pdf.

Elsby, Michael W. L., Bart Hobijn, and Ayşegül Şahin. 2013. "The Decline of the U.S. Labor Share." *Brookings Papers on Economic Activity*, Fall, 1–52.

Faberman, Jason, and Alejandro Justiniano. 2015. "Job Switching and Wage Growth." *Chicago Fed Letter*, no. 337. Federal Reserve Bank of Chicago.

Faccini, Renato, and Leonardo Melosi. 2021. "Bad Jobs and Low Inflation." Working Paper 2020-09. Chicago: Federal Reserve Bank of Chicago. https://doi.org/10.21033/wp-2020-09.

Feenstra, Robert C., Philip Luck, Maurice Obstfeld, and Katheryn N. Russ. 2018. "In Search of the Armington Elasticity." *Review of Economics and Statistics* 100, no. 1: 135–50.

Forbes, Kristin J. 2019. "Inflation Dynamics: Dead, Dormant, or Determined Abroad?" *Brookings Papers on Economic Activity*, Fall, 257–319.

Karahan, Fatih, Ryan Michaels, Benjamin Pugsley, Ayşegül Şahin, and Rachel Schuh. 2017. "Do Job-to-Job Transitions Drive Wage Fluctuations over the Business Cycle?" *American Economic Review* 107, no. 5: 353–57.

Moscarini, Giuseppe, and Fabien Postel-Vinay. 2017. "The Relative Power of Employment-to-Employment Reallocation and Unemployment Exits in Predicting Wage Growth." *American Economic Review* 107, no. 5: 364–68.

Moscarini, Giuseppe, and Fabien Postel-Vinay. 2022. "The Job Ladder: Inflation vs. Reallocation." Working Paper. https://cpb-us-w2.wpmucdn.com/campuspress.yale.edu/dist/1/1241/files/2022/09/nominal-rigidities_SA.pdf.

Obstfeld, Maurice. 2020. "Global Dimensions of U.S. Monetary Policy." *International Journal of Central Banking* 16, no. 1: 73–132.

Perry, George L. 1970. "Changing Labor Markets and Inflation." *Brookings Papers on Economic Activity*, no. 3: 411–48.

Pissarides, Christopher A. 1985. "Short-Run Equilibrium Dynamics of Unemployment, Vacancies, and Real Wages." *American Economic Review* 75, no. 4: 676–90.

**GENERAL DISCUSSION** James Stock commented that the ratio of the number of vacancies to the number of unemployed ($V/U$) and the natural rate of unemployment ($U^*$) are mathematically equivalent, as both quantities have just one time-varying slack parameter.

Robert Hall said that while $V/U$ is generally a good measure of labor market tightness, during the COVID-19 pandemic a complication arose of laid-off workers subject to recall, who are not measured in $V$ and so must be removed from $U$. He added that making such a correction would be feasible and yield more sensible results.

Austan Goolsbee argued that comparing quantities involving vacancies and unemployment (such as *V/U*) across many decades is problematic, due to changing definitions of who is considered unemployed versus not in the labor force, such as the consideration of disability.

Alan Blinder asked whether online job boards have increased the ease of posting a vacancy, leading to duplicate vacancies and thus an aggregate measure of vacancy that is inconsistent with past measures.

Ricardo Reis suggested that the paper modify its metric of inflation expectations, from the Society of Professional Forecasters' ten-year median inflation expectations to the University of Michigan Survey of Consumers' one-year mean inflation expectations. Reis argued that professionals as a population and medians as a statistic, which the paper uses, are too stable recently and contain very little signal. A survey of households (such as Michigan's) and a mean measure that is more affected by the answers of the tail would be preferable. Further, with reference to past work by Hazell and others, Reis added that the theoretical case for using long-run inflation expectations of ten years, as used in the paper, relies on including in the regression long-run unemployment expectations, which the paper does not do. Instead, one-year inflation expectations are consistent with the short-run unemployment measure used in the paper.[1]

Blinder criticized the definition of core inflation used by the authors, which excludes unpredictable components of inflation. He contended instead that core inflation was intended to measure components which may be affected by aggregate demand policies, primarily monetary policy. He observed that the paper incorrectly removed automobile prices from core inflation, even though monetary policy does directly affect the automobile market through interest rates on auto loans.

Robert Gordon asked why the authors had chosen a cubic functional form for their regression, which would imply that a low *V/U* leads to rapid disinflation, contrary to evidence from 2009 and 2010. He added that it was the failure of inflation to slow down in the presence of high unemployment after the Great Recession that had discredited the Phillips curve.

Justin Wolfers expressed skepticism of the paper's results, given the small number of data points corresponding to the large number of degrees of freedom available for curve-fitting. Wolfers listed a number of such degrees of freedom available to researchers, including the type of inflation

1. Jonathan Hazell, Juan Herreño, Emi Nakamura, and Jón Steinsson, "The Slope of the Phillips Curve: Evidence from U.S. States," *Quarterly Journal of Economics* 137, no. 3 (2022): 1299–344, https://doi.org/10.1093/qje/qjac010.

metric, the type and time horizon of inflation expectation, the choice of survey data source, the measure of labor market slack, the time variance of model coefficients, the model lag structure and nonlinearities, and the inclusion of supply shocks and regime shifts. He argued that given such a large number of degrees of freedom, any Phillips curve could be plausibly claimed to account for the observed path of inflation.

James Hamilton noted that the model used in the paper was highly nonlinear based on a cubic function of the ratio $V/U$. He suggested instead starting with a specification that is linear in the logs of the primitive variables $V$ and $U$, similar to equations presented in Ayşegül Şahin's discussion paper, and then seeing if it was helpful to generalize this to a function that is quadratic in logs.

Hall contended that the paper's use of a complicated autoregressive specification was not necessary or explanatory and that it would be preferable to return to a more fundamental microeconomic view of inflation being a result of buyers and sellers agreeing to higher prices. Hall added that the Beveridge curve is not a structural object, in agreement with Şahin.

Emi Nakamura echoed the challenges of modeling specifications for a Phillips curve, particularly identification in a time series context.

Maurice Obstfeld argued that the present inflation scenario was not in the standard Phillips curve region and should not be modeled as such, in agreement with Jason Furman, and with reference to John Maynard Keynes's argument in his 1940 book titled *How to Pay for the War*.[2] Rather, Obstfeld said that present inflation in the United States should be understood to be a result of nominal demand exceeding nominal supply, due to a highly supply-constrained economy resembling postwar Europe or present-day Ukraine.

Nakamura asked the authors about the role the sectoral shocks and relative price shocks play in inflation, and especially how they affect future inflation projections. Nakamura suggested that when comparing the present inflation to that of the 1970s, a parallel of large relative price variability arises; this was a part of the reason for the belief that inflation would be transitory and that there would be a reduction in relative price shocks, connected to the issue of sectoral shifts and supply shocks.

Goolsbee stated that if inflation were caused by supply shocks, then the forecast of inflation is equivalent to a forecast of the likelihood of reversing the supply shocks. Further, Goolsbee argued that the fact that before the

2. John Maynard Keynes, *How to Pay for the War: A Radical Plan for the Chancellor of the Exchequer* (London: Macmillan, 1940), available at https://fraser.stlouisfed.org/title/6021.

COVID-19 pandemic, the unemployment rate was 3.5 percent with little inflation, but that later inflation increased when unemployment was at 6 percent, and suggested that inflation had a significant supply shock component even before looking for nonlinearity in the Phillips curve.

Claudia Sahm agreed with Goolsbee in arguing that the Phillips curve is inappropriate to the study of present inflation, as the Phillips curve is far better specified for demand shocks than to the supply shocks that underlie present-day inflation; using the Phillips curve may therefore lead us astray on how inflation and unemployment need to be addressed. She conceded that the paper made progress on understanding inflation and the Phillips curve in the context of supply shocks, with decompositions of the median CPI and headline inflation, and accounting for supply chain shocks.

Laurence Meyer stated that a nonlinear Phillips curve and a higher non-accelerating inflation rate of unemployment were persuasive conclusions of the empirical research.

Laurence Ball accepted Şahin's and Furman's critiques of the Phillips curve, particularly that historically attempts to model it have suffered from poor specification, although little could be done in response except to continue to improve modeling efforts. Ball added that either supply or demand shocks can cause relative shocks within sectors, and that the paper does not disaggregate the effects of supply from demand but instead focuses on how labor markets and relative sectoral shocks feed into inflation.

Goolsbee added that the fraction of inflation that is caused by energy will make a huge difference, although he agreed with Furman on the point of some measures of supply chain tightness possibly being measures of demand, not supply. Goolsbee suggested that the authors should have considered the effect of productivity on wages and prices, particularly given fluctuating productivity through the COVID-19 pandemic period.

Sahm argued that the paper did not adequately account for labor market shortages due to COVID-19 pandemic-imposed illness and mortality, which may take a long time to dissipate. As a comparison, she referenced an analysis of the effect of pandemics on the labor market.[3]

Meyer said that a regime shift, from a low-inflation to a high-inflation regime, should be a critical consideration in modeling inflation. An important component of this regime shift is the much higher importance of short-term inflation expectations in wage bargaining, relative to long-run inflation

3. Oscar Jorda, Sanjay R. Singh, and Alan M. Taylor, "Longer-Run Economic Consequences of Pandemics," working paper 2020-09, Federal Reserve Bank of San Francisco, https://doi.org/10.24148/wp2020-09.

expectations. Meyer added that adaptive inflation expectations should be considered.

Gordon emphasized that the Federal Reserve Board could choose an inflation target of 2 percent or 3 percent, and that sticking to a 2 percent target would be costly and warrants public discussion. Blinder responded that he did not expect the Federal Reserve to change the target.

Gordon stated that Furman's parameter choices were extremely optimistic; contrary to Furman's choices, inflation expectations are unlikely to be re-anchored to pre-pandemic levels and *V/U* is unlikely to return to two-thirds of the way back to pre-2019 levels.

Frederic Mishkin expressed pessimism regarding the near future of unemployment, arguing that the Federal Reserve may need to cause a serious recession to control inflation. Mishkin argued that the Federal Reserve has made two serious mistakes in addressing inflation—it abandoned its preemptive strategy, and it didn't specify a horizon for average inflation targeting. Due to these mistakes, inflation expectations are less anchored and Federal Reserve actions need to be tougher than they otherwise would be.

Reis disputed Gordon's view, instead stating that he was optimistic about inflation reducing going forward, noting that he observed a dramatic re-anchoring of expectations in the Michigan mean of one-year and five-year inflation expectation numbers in the preceding three-month period, maybe as a result of communications from the Federal Reserve becoming tougher on inflation.

Responding to points raised in the discussion papers, Ball noted that Şahin's outcomes were similar to the authors' outcomes. Ball agreed with Şahin's suggestion that *V/U* and headline shocks may be influenced by similar factors, such as the overheating which contributed to supply chain troubles. Ball added that he did not understand Şahin's argument that for the authors' two-stage regression to be valid, supply side variables, such as wages, must be uncorrelated with labor market tightness; however, he stated that the two quantities were not strongly correlated empirically.

# ONLINE APPENDIX

## "Understanding U.S. Inflation During the COVID Era"

Laurence Ball, Daniel Leigh, and Prachi Mishra

October 24, 2022

## Alternative Measures of Core Inflation

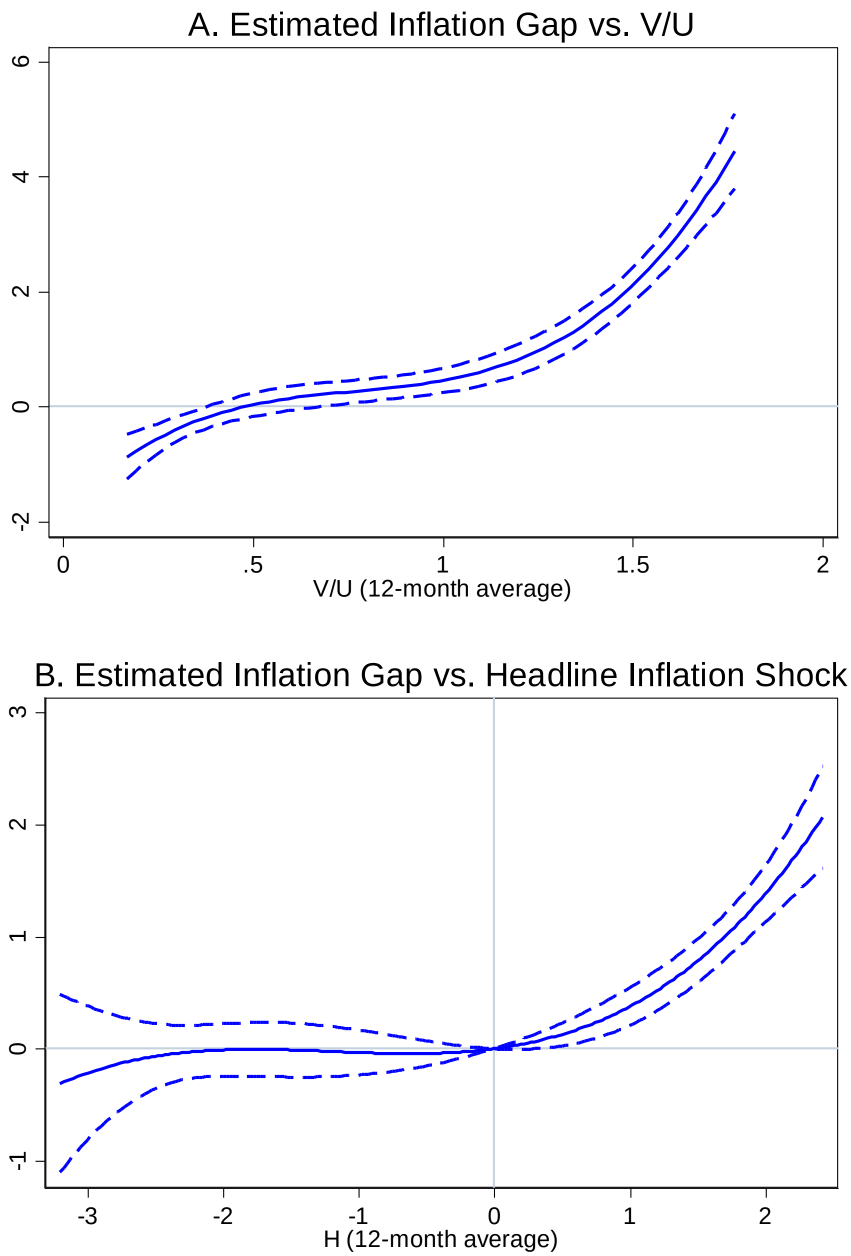
Here we examine the robustness of our results to two alternative measures of core inflation, median PCE Inflation (from the Federal Reserve Bank of Cleveland) and trimmed mean PCE inflation (from the Federal Reserve Bank of Dallas). We find that the results are similar to those obtained with median CPI inflation.

**Table 1A. Phillips Curve Estimates: Median PCE Inflation**

| | (1) Quarterly 1985-2019 | (2) Quarterly 1985-2022 | (3) Monthly 1985-2019 | (4) Monthly 1985-2022 |
|---|---|---|---|---|
| V/U | 6.966** | 6.598*** | 5.530 | 6.931*** |
| | (3.472) | (1.867) | (3.918) | (1.924) |
| (V/U)-squared | -7.852 | -7.540*** | -5.719 | -8.208*** |
| | (5.420) | (2.308) | (6.010) | (2.362) |
| (V/U)-cubed | 3.137 | 3.132*** | 2.192 | 3.559*** |
| | (2.538) | (0.837) | (2.789) | (0.843) |
| H | 0.128 | 0.122 | 0.090 | 0.158 |
| | (0.113) | (0.097) | (0.127) | (0.114) |
| H-squared | 0.144 | 0.166*** | 0.145* | 0.171*** |
| | (0.099) | (0.027) | (0.084) | (0.024) |
| H-cubed | 0.035 | 0.045** | 0.049 | 0.048* |
| | (0.034) | (0.020) | (0.033) | (0.024) |
| Constant | -1.858*** | -1.782*** | -1.590** | -1.827*** |
| | (0.617) | (0.420) | (0.715) | (0.439) |
| Observations | 140 | 150 | 420 | 452 |
| R-squared | 0.312 | 0.596 | 0.162 | 0.435 |
| Rbar-squared | 0.281 | 0.580 | 0.149 | 0.428 |

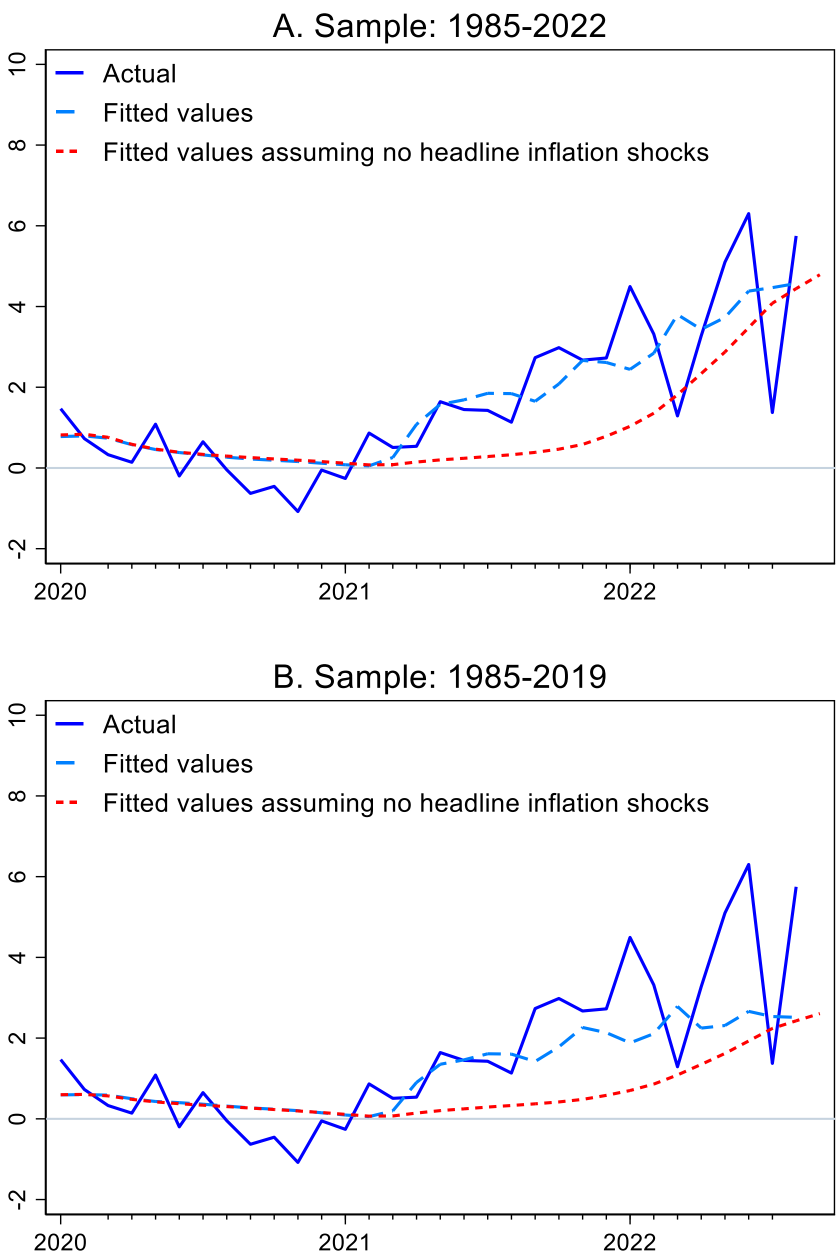
Notes: V/U denotes ratio of vacancies to unemployed (4-quarter or 12-month average). H denotes headline-inflation shock (4-quarter or 12-month average). Newey-West standard errors with 4 lags (quarterly data) and 12 lags (monthly data) in parentheses. ***, **, and * denote statistical significance at the 1,5, and 10 percent level, respectively.

**Figure 6A. Estimated PCE Inflation Gap as a Function of Slack and Headline-inflation Shocks, 1985-2022**
(Percentage points; monthly data)




Note: Panel A reports fitted values for constant term and V/U terms from equation estimates reported in Table 1A (column 4). Panel B reports fitted values for headline-inflation shock (H) terms. Bands report 95 percent confidence interval. Inflation gap denotes monthly annualized median PCE inflation minus long-term Survey of Professional Forecasters inflation expectations.

**Figure 7A. Predictions for PCE Median Inflation Gap During 2020-2022**
(Percentage points)



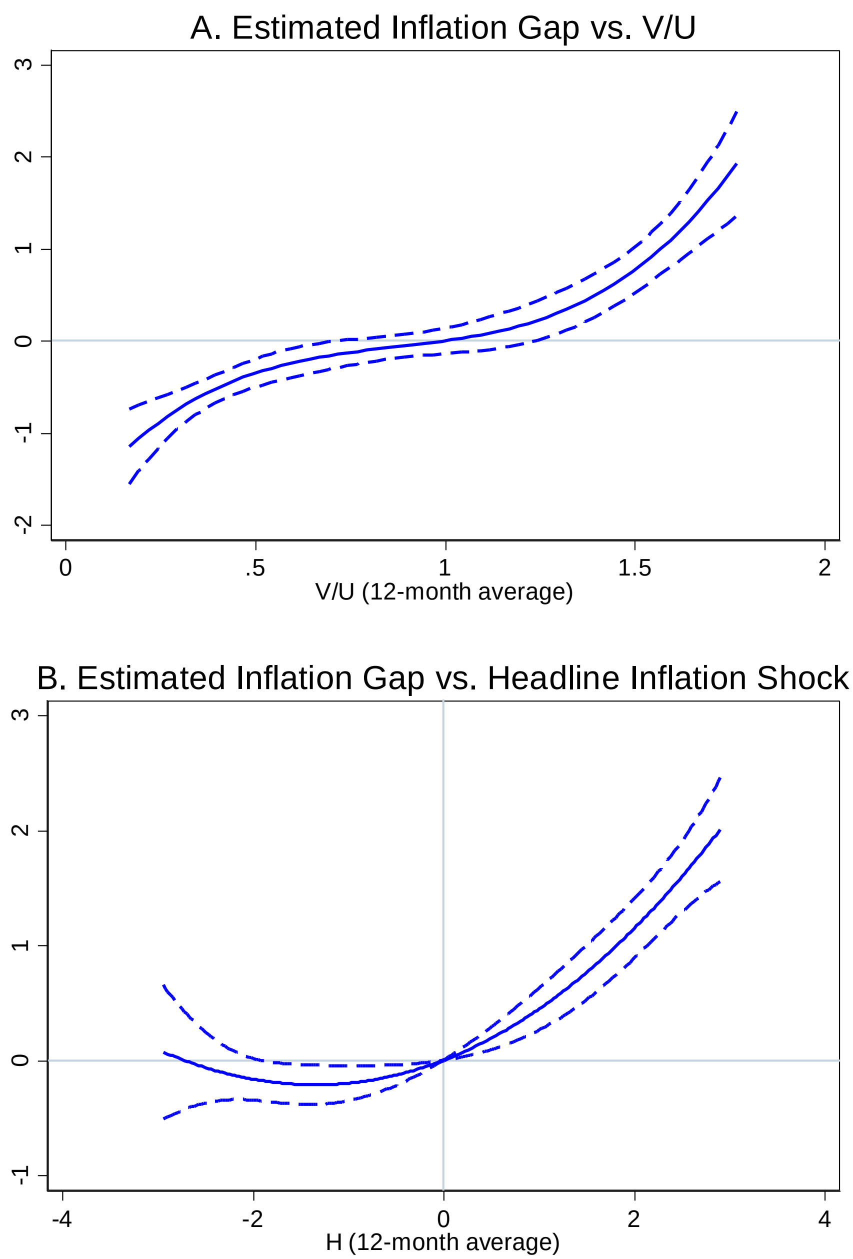

Note: Figure reports fitted values from Phillips Curve model with PCE Median estimated for the full sample (Table 1A column 4) and for the pre-pandemic sample (Table 1A column 3).

## Table 1B. Phillips Curve Estimates: Trimmed Mean PCE Inflation

| | (1)<br>Quarterly<br>1985-2019 | (2)<br>Quarterly<br>1985-2022 | (3)<br>Monthly<br>1985-2019 | (4)<br>Monthly<br>1985-2022 |
|---|---|---|---|---|
| V/U | 6.504* | 4.417** | 5.367 | 5.396*** |
| | (3.426) | (2.120) | (3.774) | (1.903) |
| (V/U)-squared | -7.422 | -4.086 | -5.696 | -5.659** |
| | (5.218) | (2.649) | (5.674) | (2.273) |
| (V/U)-cubed | 2.964 | 1.379 | 2.183 | 2.167*** |
| | (2.400) | (0.997) | (2.596) | (0.796) |
| Headline-inflation shock | 0.333*** | 0.279*** | 0.307*** | 0.320*** |
| | (0.099) | (0.093) | (0.110) | (0.100) |
| Headline-inflation shock-squared | 0.088 | 0.126*** | 0.094 | 0.122*** |
| | (0.102) | (0.021) | (0.095) | (0.020) |
| Headline-inflation shock-cubed | -0.021 | 0.006 | -0.006 | 0.002 |
| | (0.038) | (0.018) | (0.036) | (0.018) |
| Constant | -2.086*** | -1.722*** | -1.878** | -1.907*** |
| | (0.651) | (0.489) | (0.738) | (0.456) |
| Observations | 140 | 150 | 420 | 452 |
| R-squared | 0.305 | 0.548 | 0.155 | 0.388 |
| Rbar-squared | 0.274 | 0.529 | 0.143 | 0.379 |

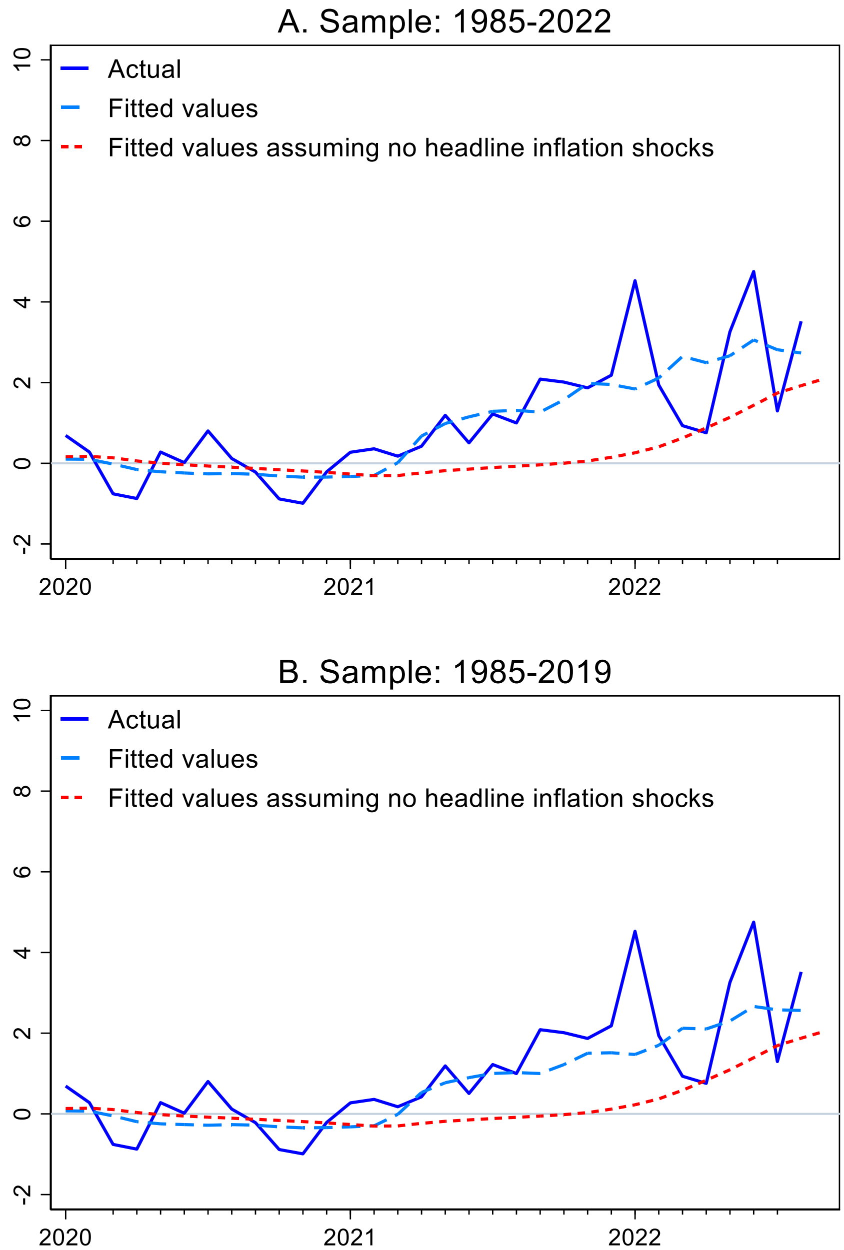
Notes: “V/U” denotes ratio of vacancies to unemployed (4-quarter or 12-month average). “H” denotes headline-inflation shock (4-quarter or 12-month average). Newey-West standard errors with 4 lags (quarterly data) and 12 lags (monthly data) in parentheses. ***, **, and * denote statistical significance at the 1,5, and 10 percent level, respectively.

**Figure 6B. Estimated Trimmed Mean PCE Inflation Gap as a Function of Slack and Headline-inflation Shocks, 1985-2022**
(Percentage points; monthly data)




Note: Panel A reports fitted values for constant term and V/U terms from equation estimates reported in Table 1B (column 4). Panel B reports fitted values for headline-inflation shock (H) terms. Bands report 95 percent confidence interval. Inflation gap denotes monthly annualized trimmed mean PCE inflation minus long-term Survey of Professional Forecasters inflation expectations.

**Figure 7B. Predictions for Trimmed Mean PCE Inflation Gap During 2020-2022**
(Percentage points)

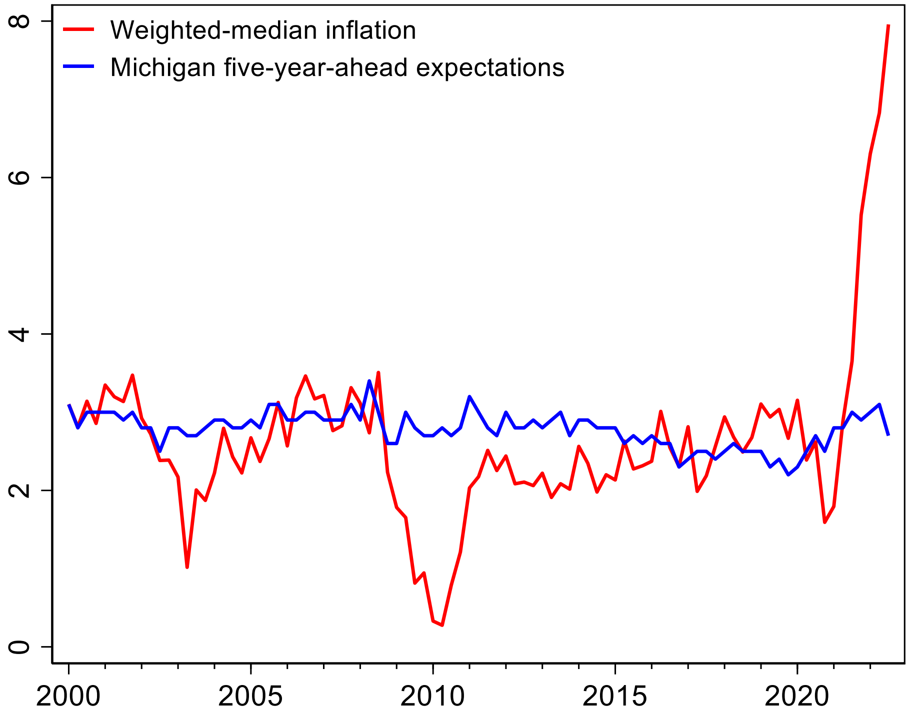



Note: Figure reports fitted values from Phillips Curve model with trimmed mean PCE estimated for the full sample (Table 1B column 4) and for the pre-pandemic sample (Table 1B column 3).

**Measuring Inflation Expectations with University of Michigan Five-year-ahead CPI Inflation Expectations**

Here we examine another common measure of inflation expectations, the five-year-ahead forecast from the Michigan Survey of Consumers. We find that the results are similar to those for the 10-year-ahead expectations from the Survey of Professional Forecasters.

**Figure 2C. 5-year-ahead CPI Inflation Expectations and Median CPI Inflation, 2000-2022**



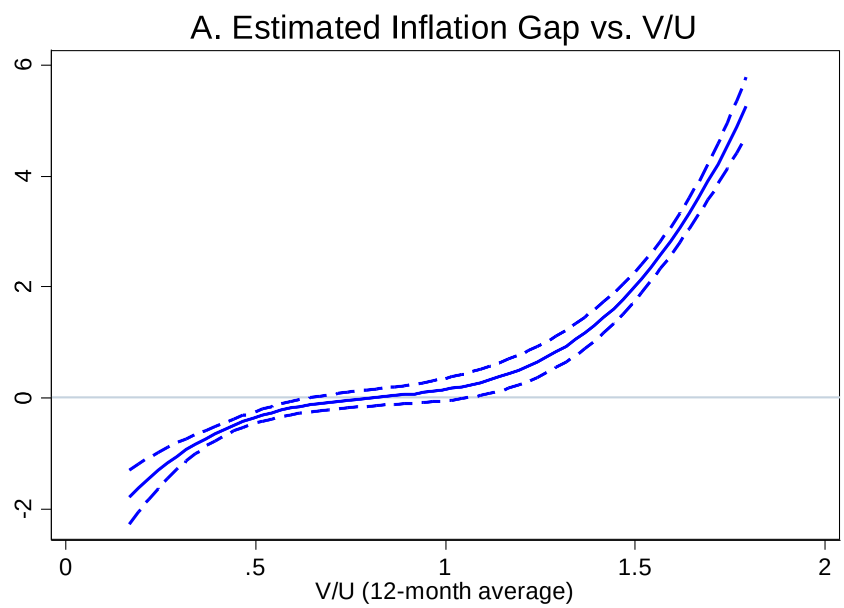

Note: Figure reports five-year-ahead CPI inflation forecasts from the University of Michigan Survey of Consumers.

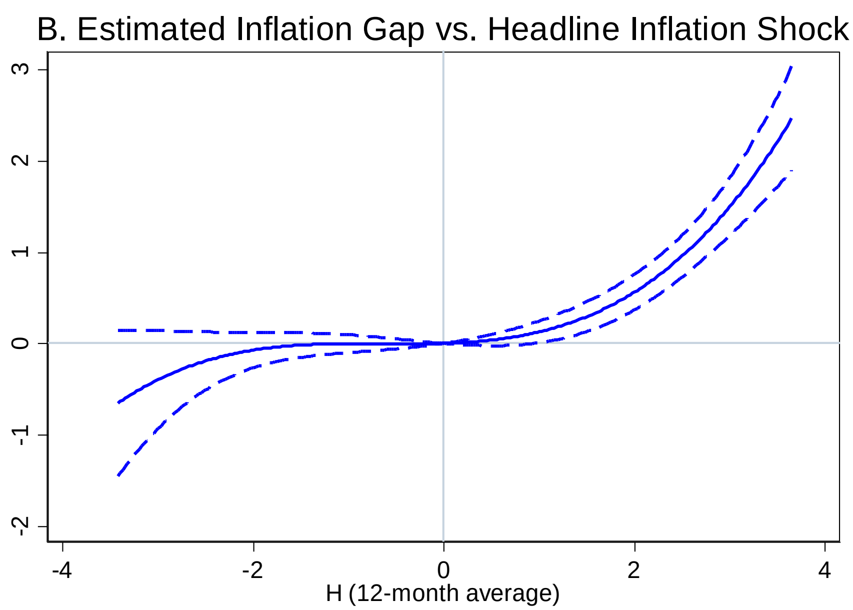
**Table 1C. Phillips Curve Estimates: Median CPI Inflation. Michigan 5-year-ahead Instead of SPF 10-year-ahead Inflation Expectations**

| | (1) Quarterly 1985-2019 | (2) Quarterly 1985-2022 | (3) Monthly 1985-2019 | (4) Monthly 1985-2022 |
|---|---|---|---|---|
| V/U | 14.082*** | 10.305*** | 12.358*** | 10.806*** |
| | (3.287) | (1.919) | (4.056) | (2.064) |
| (V/U)-squared | -17.830*** | -11.792*** | -14.792** | -12.428*** |
| | (5.085) | (2.261) | (6.163) | (2.414) |
| (V/U)-cubed | 7.606*** | 4.728*** | 6.094** | 5.048*** |
| | (2.373) | (0.773) | (2.850) | (0.835) |
| H | 0.018 | -0.013 | 0.037 | 0.033 |
| | (0.055) | (0.059) | (0.064) | (0.061) |
| H-squared | 0.075** | 0.052*** | 0.054* | 0.061*** |
| | (0.038) | (0.013) | (0.033) | (0.019) |
| H-cubed | 0.030* | 0.027*** | 0.027 | 0.031*** |
| | (0.016) | (0.008) | (0.018) | (0.010) |
| Constant | -3.819*** | -3.139*** | -3.553*** | -3.282*** |
| | (0.649) | (0.483) | (0.813) | (0.527) |
| Observations | 140 | 151 | 420 | 453 |

Notes: "V/U" denotes ratio of vacancies to unemployed (4-quarter or 12-month average). "H" denotes headline-inflation shock (4-quarter or 12-month average). Newey-West standard errors with 4 lags (quarterly data) and 12 lags (monthly data) in parentheses. ***, **, and * denote statistical significance at the 1,5, and 10 percent level, respectively.

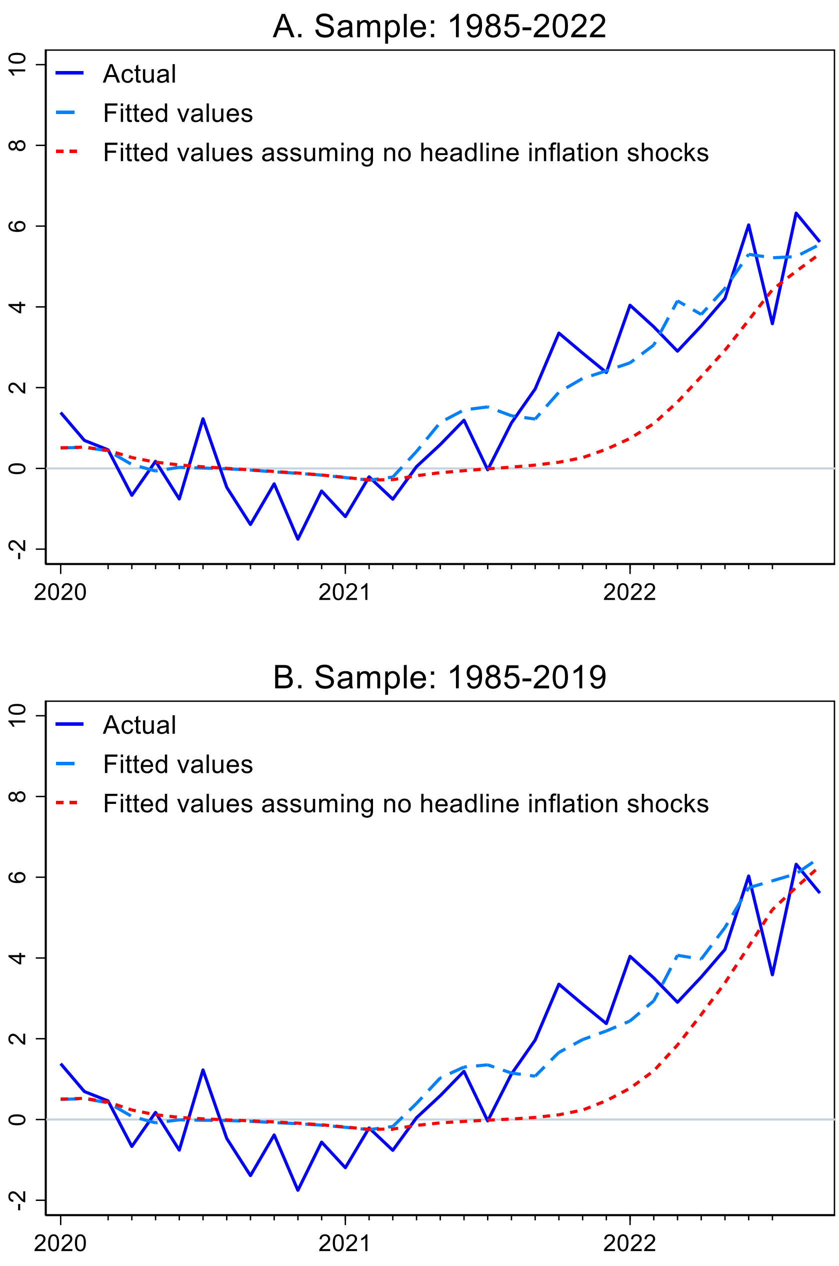
**Figure 6C. Estimated Inflation Gap as a Function of Slack and Headline-inflation Shocks, 1985-2022. Michigan 5-year-ahead expectations (instead of SPF 10-year)**
(Percentage points; monthly data)




Note: Panel A reports fitted values for constant term and V/U terms from equation estimates reported in Table 1C (column 4). Panel B reports fitted values for headline-inflation shock (H) terms. Bands report 95 percent confidence interval. Inflation gap denotes monthly annualized median CPI inflation minus 5-year ahead inflation expectations from the Michigan Survey of Consumers.

**Figure 7C. Predictions for Median Inflation Gap During 2020-2022. Michigan 5-year-ahead (instead of SPF 10-year)**
(Percentage points)




Note: Figure reports fitted values from Phillips Curve model with five-year-ahead inflation expectations from the Michigan Survey of Consumers estimated for the full sample (Table 1C column 4) and for the pre-pandemic sample (Table 1C column 3).

### Measuring Labor Markets Conditions with the Unemployment Gap

Here we measure labor market conditions with the difference between the unemployment rate and its natural rate as estimated by the CBO. With the unemployment gap, the fit of our Phillips curve is somewhat worse. For example, with monthly pre-pandemic data, the Rbar-squared is 0.27 and 0.25 for V/U and the U gap respectively. For the full sample through 2022, the corresponding numbers are 0.51 and 0.46 respectively. In a horse race with both measures of labor market conditions, both are statistically significant. However, once V/U is included, the increase in Rbar-squared from including the U gap is small. For example, for monthly data, for the full sample, the increase is only 0.005. In contrast, when the U gap is included, adding V/U increases Rbar-squared by 0.055.

**Table 1D. Phillips Curve Estimates with Quarterly Data: U-U* vs. V/U**

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | 1985-2019 | 1985-2022 | 1985-2019 | 1985-2022 | 1985-2019 | 1985-2022 |
| U-U* | -0.381*** | -0.455*** | | | -0.378* | -0.302* |
| | (0.103) | (0.128) | | | (0.213) | (0.158) |
| (U-U*)-squared | 0.154* | 0.168* | | | 0.279*** | 0.161* |
| | (0.083) | (0.095) | | | (0.096) | (0.094) |
| (U-U*)-cubed | -0.027 | -0.027 | | | -0.032** | -0.022 |
| | (0.017) | (0.019) | | | (0.014) | (0.016) |
| H | -0.130* | -0.050 | 0.021 | 0.031 | 0.021 | -0.039 |
| | (0.075) | (0.123) | (0.068) | (0.074) | (0.075) | (0.077) |
| H-squared | 0.192*** | 0.158*** | 0.155*** | 0.081*** | 0.132*** | 0.106*** |
| | (0.033) | (0.033) | (0.041) | (0.016) | (0.038) | (0.020) |
| H-cubed | 0.091*** | 0.061*** | 0.054*** | 0.026** | 0.041** | 0.042*** |
| | (0.018) | (0.015) | (0.019) | (0.010) | (0.020) | (0.012) |
| V/U | | | 11.039*** | 9.024*** | 28.194*** | 10.287*** |
| | | | (3.645) | (2.120) | (7.461) | (2.725) |
| (V/U)-squared | | | -13.261** | -10.083*** | -38.038*** | -12.714*** |
| | | | (5.485) | (2.383) | (11.034) | (3.173) |
| (V/U)-cubed | | | 5.541** | 4.032*** | 16.101*** | 5.061*** |
| | | | (2.530) | (0.789) | (4.882) | (1.057) |
| Constant | -0.074 | -0.007 | -3.026*** | -2.616*** | -6.598*** | -2.654*** |
| | (0.081) | (0.075) | (0.747) | (0.557) | (1.559) | (0.733) |
| Observations | 140 | 151 | 140 | 151 | 140 | 151 |
| R-squared | 0.489 | 0.595 | 0.512 | 0.761 | 0.586 | 0.777 |
| Rbar-squared | 0.466 | 0.578 | 0.490 | 0.751 | 0.558 | 0.762 |

Notes: "U-U*" denotes gap between unemployment rate and Congressional Budget Office estimate of natural rate (4-quarter or 12-month average). "V/U" denotes ratio of vacancies to unemployed (4-quarter or 12-month average). "H" denotes headline-inflation shock (4-quarter or 12-month average). Newey-West standard errors with 4 lags (quarterly data) and 12 lags (monthly data) in parentheses. ***, **, and * denote statistical significance at the 1,5, and 10 percent level, respectively.

**Table 1D (Continued). Phillips Curve Estimates with Monthly Data: U-U* vs. V/U**

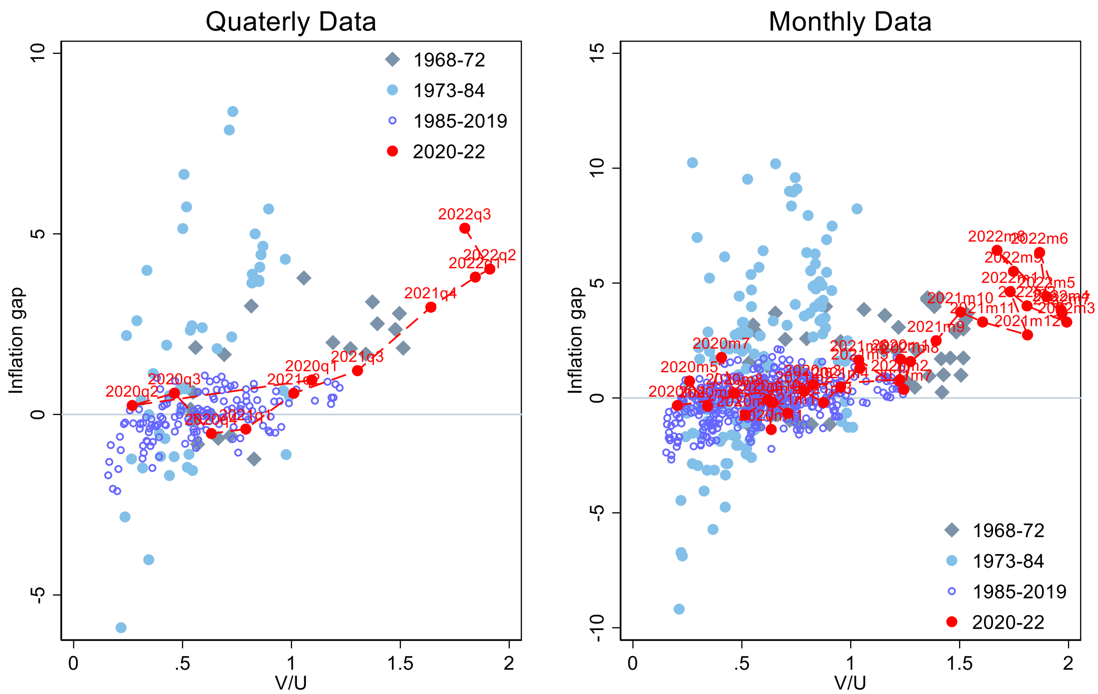
| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | 1985-2019 | 1985-2022 | 1985-2019 | 1985-2022 | 1985-2019 | 1985-2022 |
| U-U* | -0.402*** | -0.457*** | | | -0.318 | -0.225 |
| | (0.095) | (0.113) | | | (0.195) | (0.141) |
| (U-U*)-squared | 0.145** | 0.154* | | | 0.279*** | 0.133 |
| | (0.073) | (0.082) | | | (0.089) | (0.088) |
| (U-U*)-cubed | -0.023 | -0.024 | | | -0.030** | -0.017 |
| | (0.015) | (0.016) | | | (0.013) | (0.015) |
| H | -0.131 | -0.036 | 0.010 | 0.058 | 0.041 | 0.005 |
| | (0.080) | (0.117) | (0.075) | (0.068) | (0.076) | (0.073) |
| H-squared | 0.142*** | 0.159*** | 0.128*** | 0.089*** | 0.107*** | 0.104*** |
| | (0.031) | (0.037) | (0.033) | (0.019) | (0.030) | (0.021) |
| H-cubed | 0.079*** | 0.065*** | 0.053*** | 0.031*** | 0.037** | 0.041*** |
| | (0.019) | (0.017) | (0.019) | (0.011) | (0.018) | (0.013) |
| V/U | | | 9.553** | 9.140*** | 29.920*** | 11.307*** |
| | | | (3.791) | (1.809) | (7.301) | (2.989) |
| (V/U)-squared | | | -10.879* | -10.328*** | -39.540*** | -13.617*** |
| | | | (5.743) | (2.096) | (10.612) | (3.412) |
| (V/U)-cubed | | | 4.439* | 4.241*** | 16.571*** | 5.460*** |
| | | | (2.666) | (0.727) | (4.689) | (1.147) |
| Constant | -0.047 | 0.000 | -2.759*** | -2.654*** | -7.194*** | -3.039*** |
| | (0.072) | (0.073) | (0.760) | (0.467) | (1.589) | (0.822) |
| Observations | 420 | 453 | 420 | 453 | 420 | 453 |
| R-squared | 0.259 | 0.442 | 0.284 | 0.575 | 0.329 | 0.582 |
| Rbar-squared | 0.248 | 0.435 | 0.274 | 0.569 | 0.315 | 0.574 |

Notes: “U-U*” denotes gap between unemployment rate and Congressional Budget Office estimate of natural rate (4-quarter or 12-month average). “V/U” denotes ratio of vacancies to unemployed (4-quarter or 12-month average). “H” denotes headline-inflation shock (4-quarter or 12-month average). Newey-West standard errors with 4 lags (quarterly data) and 12 lags (monthly data) in parentheses. ***, **, and * denote statistical significance at the 1,5, and 10 percent level, respectively.

**Contemporaneous V/U Instead of 4-quarter or 12-month Average**

Here we consider the relation between the median CPI inflation gap and the current level of V/U instead of the 4-quarter or 12-month average reported in the text. In the scatter plot, we see a strong positive relationship with the inflation gap, but the recent observations are more of an outlier compared to the past. For the Phillips curve equations, the coefficient estimates are similar but the R-bar-squared statistic is lower. For monthly data with the full sample, the R-bar-squared is 0.473, compared with 0.514 reported in Table 1 Column 4 of the text.

**Figure 3A. Inflation Gap vs. Ratio of *Contemporaneous* Vacancies to Unemployed (V/U)**




Note: Figure reports quarterly and monthly scatter plots of the inflation gap against the current level of V/U. Inflation gap is the difference between median and long-term expected inflation. Long-term expected inflation 10-year-ahead CPI inflation forecasts from the Survey of Professional Forecasters (SPF). “V/U” denotes contemporaneous (instead of 4-quarter or 12-month average) ratio of vacancies to unemployed.

**Table 1E. Phillips Curve Estimates: Median CPI Inflation. Contemporaneous V/U**

| | (1) Quarterly 1985-2019 | (2) Quarterly 1985-2022 | (3) Monthly 1985-2019 | (4) Monthly 1985-2022 |
|---|---|---|---|---|
| V/U | 13.506*** | 8.332*** | 13.225*** | 6.434*** |
| | (3.251) | (2.120) | (3.362) | (2.383) |
| (V/U)-squared | -17.292*** | -9.038*** | -16.678*** | -6.181** |
| | (4.899) | (2.380) | (5.038) | (2.758) |
| (V/U)-cubed | 7.379*** | 3.455*** | 7.046*** | 2.306*** |
| | (2.234) | (0.770) | (2.291) | (0.881) |
| H | 0.045 | 0.100 | 0.049 | 0.135 |
| | (0.070) | (0.095) | (0.077) | (0.107) |
| H-squared | 0.177*** | 0.052* | 0.158*** | 0.080*** |
| | (0.044) | (0.029) | (0.034) | (0.028) |
| H-cubed | 0.041** | -0.012 | 0.038** | -0.006 |
| | (0.020) | (0.019) | (0.018) | (0.022) |
| Constant | -3.453*** | -2.433*** | -3.430*** | -2.130*** |
| | (0.649) | (0.548) | (0.681) | (0.597) |
| Observations | 140 | 151 | 420 | 453 |
| R-squared | 0.483 | 0.695 | 0.279 | 0.500 |
| Rbar-squared | 0.459 | 0.683 | 0.268 | 0.493 |

Notes: “V/U” denotes contemporaneous ratios of vacancies to unemployed. “H” denotes headline-inflation shock (4-quarter or 12-month average). Newey-West standard errors with 4 lags (quarterly data) and 12 lags (monthly data) in parentheses. ***, **, and * denote statistical significance at the 1,5, and 10 percent level, respectively.

## Headline Shocks Averaged over Shorter Periods

Here we experiment with headline inflation shocks averaged over shorter periods (one, three, and six months) instead of 12 months as in Text Table 1. We find that these shorter averages explain core (median) inflation less well.

**Table 1F. Phillips Curve Estimates: Median CPI Inflation. Headline-inflation Shocks Over Different Horizons**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | 1985-2019 | 1985-2022 | 1985-2019 | 1985-2022 | 1985-2019 | 1985-2022 | 1985-2019 | 1985-2022 |
| | 1 month | 1 month | 3 months | 3 months | 6 months | 6 months | 12 months | 12 months |
| V/U | 7.967* | 7.494** | 8.105* | 7.470** | 9.265** | 7.825*** | 9.553** | 9.140*** |
| | (4.677) | (3.084) | (4.624) | (3.067) | (4.465) | (2.912) | (4.297) | (2.234) |
| (V/U)-squared | -8.586 | -8.449** | -8.833 | -8.406** | -10.555 | -8.747** | -10.879* | -10.328*** |
| | (6.860) | (3.833) | (6.781) | (3.809) | (6.569) | (3.534) | (6.435) | (2.545) |
| (V/U)-cubed | 3.410 | 3.852*** | 3.539 | 3.821*** | 4.343 | 3.856*** | 4.439 | 4.241*** |
| | (3.107) | (1.340) | (3.071) | (1.334) | (2.985) | (1.230) | (2.958) | (0.863) |
| H | 0.013 | 0.038* | 0.026 | 0.172 | 0.069 | 0.125 | 0.010 | 0.058 |
| | (0.016) | (0.019) | (0.105) | (0.117) | (0.080) | (0.092) | (0.073) | (0.075) |
| H-squared | 0.005** | 0.005** | 0.236*** | 0.243*** | 0.215*** | 0.181*** | 0.128*** | 0.089*** |
| | (0.002) | (0.002) | (0.066) | (0.059) | (0.070) | (0.040) | (0.035) | (0.019) |
| H-cubed | 0.000** | 0.000 | 0.099*** | 0.087*** | 0.059*** | 0.044*** | 0.053*** | 0.031** |
| | (0.000) | (0.000) | (0.021) | (0.023) | (0.021) | (0.016) | (0.017) | (0.012) |
| Constant | -2.377** | -2.260*** | -2.404** | -2.266*** | -2.674*** | -2.384*** | -2.759*** | -2.654*** |
| | (0.985) | (0.741) | (0.976) | (0.738) | (0.941) | (0.722) | (0.879) | (0.586) |
| Observations | 420 | 453 | 420 | 453 | 420 | 453 | 420 | 453 |
| R-squared | 0.255 | 0.505 | 0.271 | 0.515 | 0.269 | 0.529 | 0.284 | 0.575 |
| Rbar-squared | 0.244 | 0.498 | 0.260 | 0.509 | 0.258 | 0.522 | 0.274 | 0.569 |

Notes: "V/U" denotes ratio of vacancies to unemployed (12-month average). "H" denotes headline-inflation shock (12-month average). Newey-West standard errors with 12 lags in parentheses. ***, **, and * denote statistical significance at the 1,5, and 10 percent level, respectively.

**Core Inflation Measured by CPI Inflation Excluding Food and Energy**

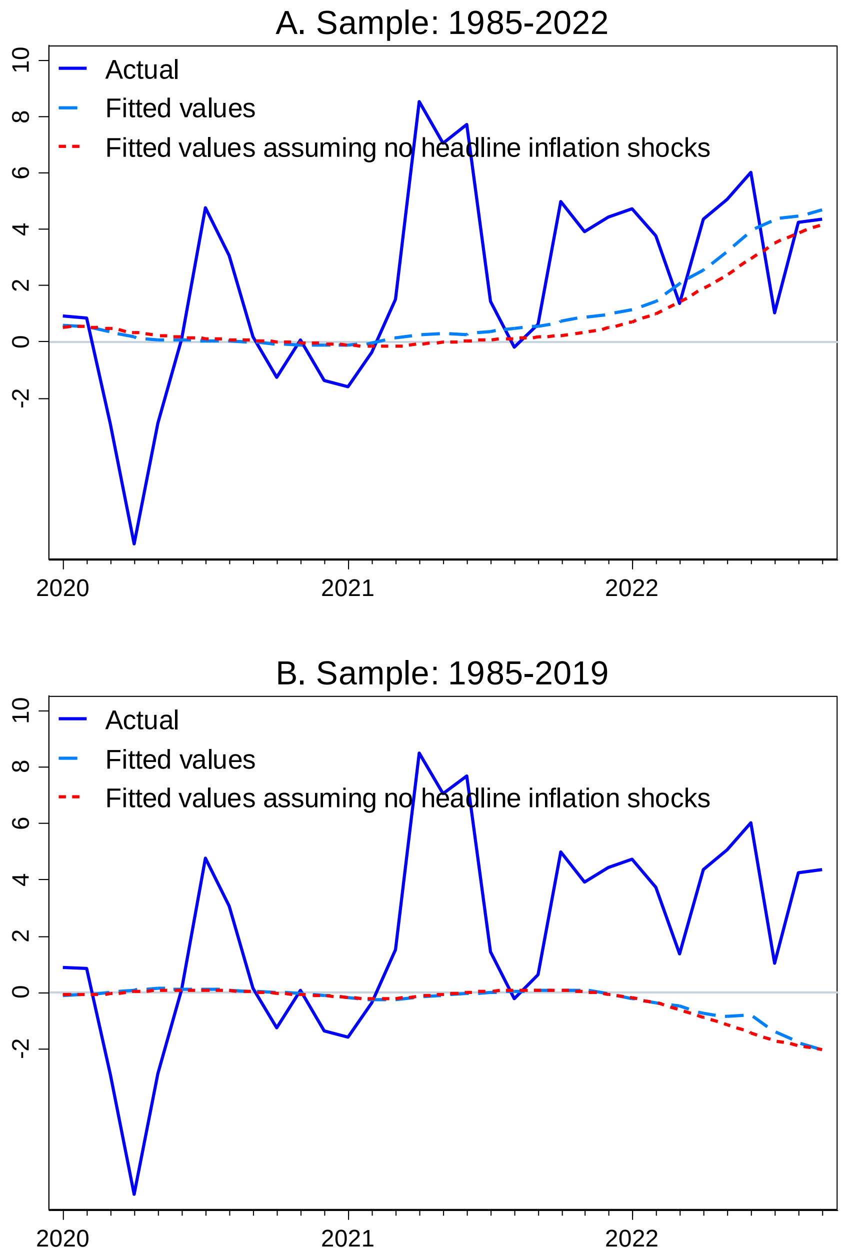
Here we report a version of the regressions in Table 1 and Figure 7 in the text with core inflation measured by CPI inflation excluding food and energy (XFE). Headline shocks are the deviations of headline inflation from XFE inflation, which are determined by changes in the relative price of food and energy. We find no evidence of a pass-through from past headline-inflation shocks into core inflation—a result that we attribute to the flawed measure of core—we find headline-inflation shocks to be jointly insignificant in all specifications in contrast to the strong joint significance when we use median CPI inflation. In addition, our core-inflation equation fails to predict any rise in inflation during the pandemic era, in contrast to the equation's good performance when core is measured by weighted median inflation.

**Table 1G. Phillips Curve Estimates: CPI Inflation Excluding Food and Energy**

| | (1) Quarterly 1985-2019 | (2) Quarterly 1985-2022 | (3) Monthly 1985-2019 | (4) Monthly 1985-2022 |
|---|---|---|---|---|
| V/U | 3.855 | 6.563* | 2.520 | 7.946** |
| | (4.091) | (3.407) | (4.515) | (3.876) |
| (V/U)-squared | -2.690 | -7.142 | -0.413 | -9.000* |
| | (6.349) | (4.688) | (6.981) | (5.191) |
| (V/U)-cubed | 0.467 | 2.952* | -0.667 | 3.680* |
| | (2.983) | (1.747) | (3.288) | (1.888) |
| H | -0.064 | 0.177 | -0.074 | 0.229 |
| | (0.090) | (0.191) | (0.100) | (0.213) |
| H-squared | 0.026 | 0.073 | 0.009 | 0.059 |
| | (0.030) | (0.053) | (0.026) | (0.049) |
| H-cubed | 0.026 | -0.001 | 0.025 | -0.010 |
| | (0.018) | (0.032) | (0.016) | (0.032) |
| Constant | -1.600** | -2.147*** | -1.372 | -2.415*** |
| | (0.778) | (0.684) | (0.879) | (0.789) |
| Observations | 140 | 151 | 420 | 453 |
| R-squared | 0.216 | 0.361 | 0.077 | 0.180 |
| Rbar-squared | 0.180 | 0.334 | 0.0632 | 0.169 |

Notes: "V/U" denotes ratio of vacancies to unemployed (4-quarter or 12-month average). "H" denotes headline-inflation shock (4-quarter or 12-month average). Newey-West standard errors with 4 lags (quarterly data) and 12 lags (monthly data) in parentheses. ***, **, and * denote statistical significance at the 1,5, and 10 percent level, respectively.

**Figure 7D. Predictions for Median Inflation Gap During 2020-2022. CPI Inflation Excluding Food and Energy** (Percentage points)




Note: Figure reports fitted values from Phillips Curve model estimated for the full sample (Table 1G column 4) and for the pre-pandemic sample (Table 1G column 3). Inflation gap denotes monthly annualized CPI inflation excluding food and energy minus long-term Survey of Professional Forecasters inflation expectations.

**Wage Phillips Curve**

Here we show estimates of the wage Phillips curve equation which are used to generate Figure 10 reported in the text. Given the lack of evidence of non-linearity in V/U in this case, we also consider a specification in which the effect of V/U is assumed to be linear.

**Table 10. Wage Phillips Curve Estimates**

| | (1)<br>1985-2019 | (2)<br>1985-2022 | (3)<br>1985-2019 | (4)<br>1985-2022 |
|---|---|---|---|---|
| V/U | -4.346 | 1.653 | 2.016*** | 2.067*** |
| | (3.200) | (2.736) | (0.241) | (0.224) |
| (V/U)-squared | 9.861* | 0.764 | | |
| | (5.058) | (3.364) | | |
| (V/U)-cubed | -4.578* | -0.392 | | |
| | (2.405) | (1.214) | | |
| H | -0.149 | -0.085 | -0.082 | -0.081 |
| | (0.125) | (0.130) | (0.120) | (0.119) |
| H-squared | -0.030 | 0.031 | -0.031 | 0.027 |
| | (0.059) | (0.032) | (0.061) | (0.028) |
| H-cubed | 0.037 | 0.056*** | 0.026 | 0.053*** |
| | (0.027) | (0.020) | (0.027) | (0.018) |
| Trend pty growth, 4-quarter avg. | 0.527*** | 0.366** | 0.507*** | 0.367*** |
| | (0.115) | (0.162) | (0.101) | (0.137) |
| Constant | -0.910* | -1.738*** | -2.055*** | -1.796*** |
| | (0.511) | (0.442) | (0.289) | (0.357) |
| Observations | 140 | 150 | 140 | 150 |
| R-squared | 0.403 | 0.442 | 0.394 | 0.441 |
| Rbar-squared | 0.372 | 0.414 | 0.371 | 0.422 |

Notes: “V/U” denotes ratio of vacancies to unemployed (4-quarter average). “H” denotes headline-inflation shock (4-quarter average). Trend productivity growth measured using output per hour in the non-farm business sector smoothed with the Hodrick-Prescott filter with λ = 16,000. Newey-West standard errors with 4 lags in parentheses. ***, **, and * denote statistical significance at the 1,5, and 10 percent level, respectively.

**Predictions for Median CPI Inflation Gap During the Pandemic: Comparison Across Models**

Here we report the regressions underlying Figure 13. Our preferred core-inflation equation performs well in this exercise, as shown by the highest adjusted R-squared. We also see that the equation with only a linear unemployment term performs quite poorly, with 8 percentage points lower adjusted R-squared compared to our preferred model. The other columns in the table show that each of our modifications of the traditional specification—the measure of slack, non-linearity, and the pass-through variable—contributes materially to the good fit of our final equation.

**Table 13A. Predictions for Median CPI Inflation Gap During the Pandemic: Comparison Across Models**

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| U-U* | -0.249*** | | | | |
| | (0.066) | | | | |
| V/U | | 1.669*** | 7.966* | 9.747** | 9.553** |
| | | (0.316) | (4.616) | (4.293) | (4.297) |
| V/U-squared | | | -8.572 | -11.324* | -10.879* |
| | | | (6.795) | (6.409) | (6.435) |
| V/U-cubed | | | 3.382 | 4.683 | 4.439 |
| | | | (3.089) | (2.945) | (2.958) |
| H | | | | 0.105* | 0.010 |
| | | | | (0.053) | (0.073) |
| H-squared | | | | | 0.128*** |
| | | | | | (0.035) |
| H-cubed | | | | | 0.053*** |
| | | | | | (0.017) |
| Constant | 0.122* | -1.045*** | -2.346** | -2.667*** | -2.759*** |
| | (0.067) | (0.218) | (0.972) | (0.889) | (0.879) |
| Observations | 420 | 420 | 420 | 420 | 420 |
| R-squared | 0.193 | 0.211 | 0.239 | 0.253 | 0.284 |
| Rbar-squared | 0.191 | 0.209 | 0.233 | 0.246 | 0.274 |

Note: Table reports predicted values based on monthly equations estimated for 1985-2019. "U-U*" denotes gap between unemployment rate and Congressional Budget Office estimate of natural rate (4-quarter or 12-month average). "V/U" denotes ratio of vacancies to unemployed (12-month average). "H" denotes headline-inflation shock (12-month average). Newey-West standard errors with 12 lags in parentheses. ***, **, and * denote statistical significance at the 1,5, and 10 percent level, respectively.

**Predictions for Median PCE Inflation Gap During the Pandemic: Comparison Across Models**

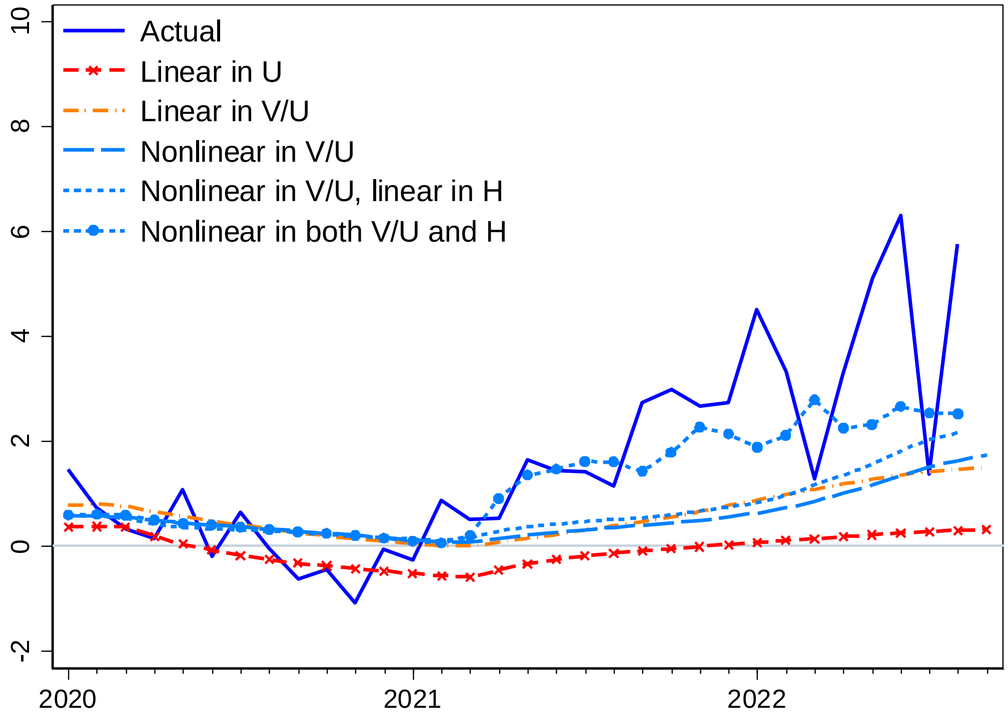
Here we repeat Table 13A reported above and Figure 13 in the text with same comparison of specifications but with core inflation measured by median PCE inflation. The results are similar to those for median CPI: the traditional equation fails to predict a significant rise in inflation; our preferred specification predicts most of the observed rise (although there is some under-prediction since May 2022); and the measure of slack, non-linearity, and the pass-through variable are all important.

**Table 13B. Predictions for Median PCE Inflation Gap During the Pandemic: Comparison Across Models**

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| U-U* | -0.187*** | | | | |
| | (0.043) | | | | |
| V/U | | 1.190*** | 4.373 | 5.113 | 5.530 |
| | | (0.234) | (3.687) | (3.833) | (3.918) |
| V/U-squared | | | -4.006 | -5.079 | -5.719 |
| | | | (5.669) | (5.896) | (6.010) |
| V/U-cubed | | | 1.402 | 1.886 | 2.192 |
| | | | (2.634) | (2.732) | (2.789) |
| H | | | | 0.059 | 0.090 |
| | | | | (0.065) | (0.127) |
| H-squared | | | | | 0.145* |
| | | | | | (0.084) |
| H-cubed | | | | | 0.049 |
| | | | | | (0.033) |
| Constant | 0.198*** | -0.641*** | -1.336* | -1.458** | -1.590** |
| | (0.067) | (0.169) | (0.701) | (0.708) | (0.715) |
| Observations | 420 | 420 | 420 | 420 | 420 |
| R-squared | 0.139 | 0.136 | 0.150 | 0.154 | 0.162 |
| Rbar-squared | 0.137 | 0.134 | 0.144 | 0.145 | 0.149 |

Note: Table reports predicted values based on monthly equations estimated for 1985-2019. "V/U" denotes ratio of vacancies to unemployed (12-month average). "H" denotes headline-inflation shock (12-month average). Newey-West standard errors with 12 lags in parentheses. ***, **, and * denote statistical significance at the 1,5, and 10 percent level, respectively.

**Figure 13B. Predictions for Median PCE Inflation Gap During the Pandemic: Comparison Across Models**




Note: Figure reports predicted values based on monthly equations estimated for 1985-2019 in Table 13B. U denotes unemployment rate, V/U denotes vacancy to unemployed ratio, H denotes headline-inflation shocks.

**Table 2A.**

Here we estimate the drivers of headline-inflation shocks in the pre-pandemic period, with the start date of the sample in each column depending on availability of data. The energy-price and auto-price variables also help explain headline shocks before the pandemic, but backlogs do not. Food-price inflation is significant before the pandemic but not during the pandemic

**Table 2A. Explaining Headline-inflation Shocks Before 2020**
(Dependent variable: Headline – Median CPI monthly annualized inflation)

A. Bivariate Regressions

| | (1) Energy price inflation | (2) Food price inflation | (3) Harper Charter Rate | (4) Baltic Dry | (5) Supplier delivery times | (6) FRBNY Supply Chain Index | (7) Backlogs of work | (8) Durable goods share of real consumption | (9) Weighted average of car inflation rates |
|---|---|---|---|---|---|---|---|---|---|
| | 0.068*** | 0.189*** | 0.001** | 0.000*** | -0.151* | 1.603*** | 0.061 | 0.159*** | 0.104** |
| | (0.007) | (0.011) | (0.001) | (0.000) | (0.091) | (0.510) | (0.121) | (0.041) | (0.042) |
| Observations | 720 | 720 | 228 | 410 | 152 | 264 | 123 | 720 | 263 |
| Start of sample | 1960m1 | 1960m1 | 2001m1 | 1985m1 | 2007m5 | 1998m1 | 2009m10 | 1960m1 | 1998m2 |
| R-squared | 0.503 | 0.170 | 0.026 | 0.041 | 0.020 | 0.061 | 0.001 | 0.014 | 0.021 |
| Rbar-squared | 0.502 | 0.169 | 0.0221 | 0.0391 | 0.0134 | 0.0571 | -0.00694 | 0.0131 | 0.0171 |

B. Selected Multivariate Regressions

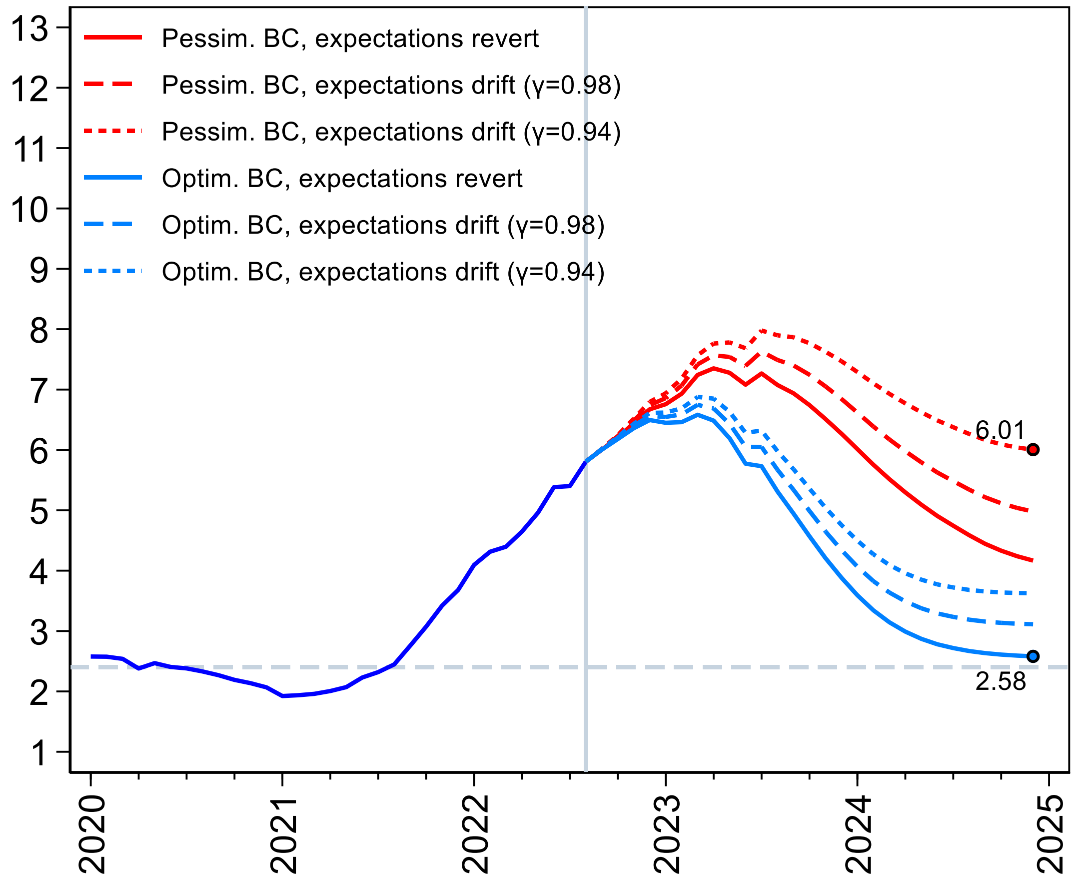
| | (1) | (2) |
|---|---|---|
| Food price inflation | 0.186*** | 0.131*** |
| | (0.009) | (0.027) |
| Energy price inflation | 0.068*** | 0.069*** |
| | (0.007) | (0.009) |
| Weighted average of car inflation rates | | 0.089*** |
| | | (0.020) |
| Constant | -0.151** | -0.807*** |
| | (0.063) | (0.123) |
| Observations | 720 | 263 |
| Start of sample | 1960m1 | 1998m2 |
| R-squared | 0.667 | 0.794 |
| Rbar-squared | 0.666 | 0.792 |

Note: Relative energy, food, and auto-related price inflation variables are created by subtracting median inflation from energy, food, and auto-related price inflation respectively, and these are in monthly annualized terms. Backlogs of work variable is taken from IHS Markit Economics. Robust standard errors in parentheses. ***, **, and * denote statistical significance at the 1,5, and 10 percent level, respectively.

**Simulations of Core (Median) PCE Inflation**

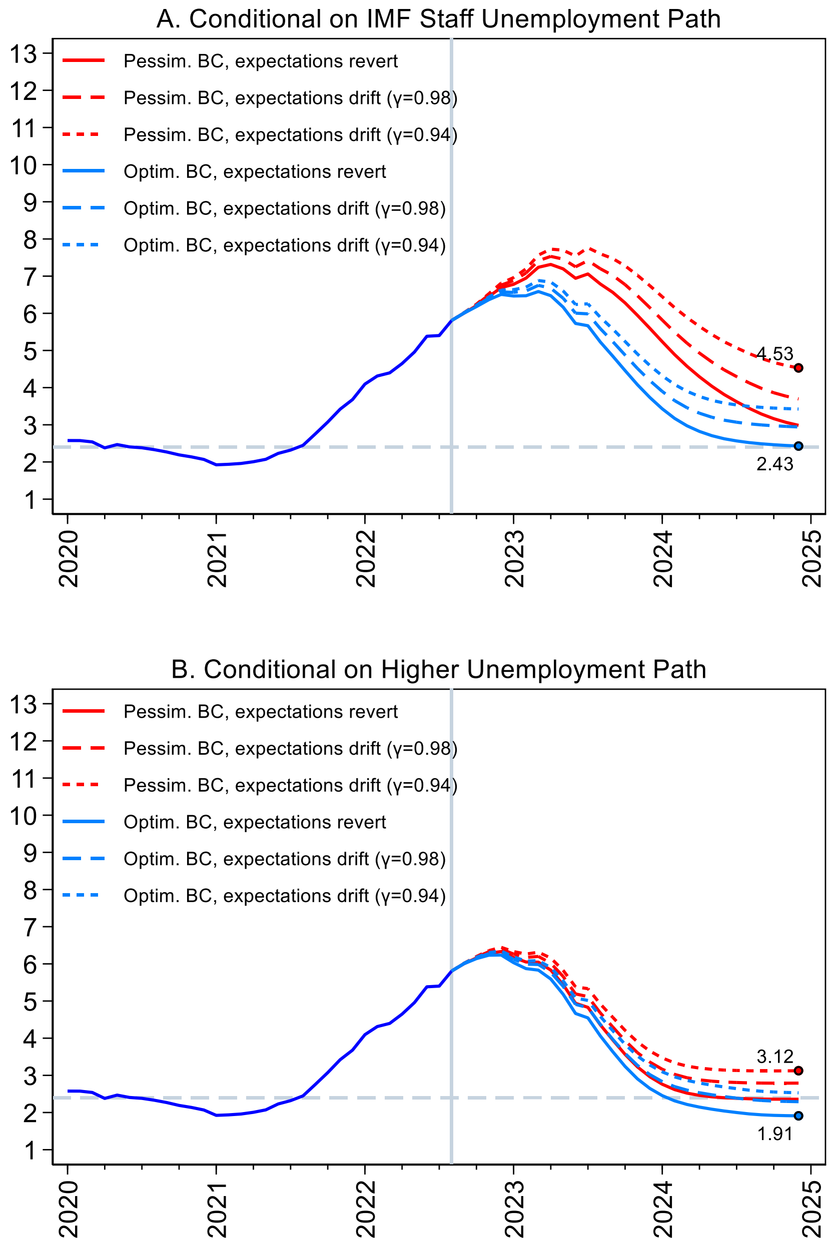
Here we report simulations of future core inflation as measured by median PCE inflation as the measure of core inflation, instead of median CPI inflation. These simulations use the Phillips curve for median PCE inflation in Table 1A column 4 and the same equations for the Beveridge curve and inflation expectations as in the text. The results, reported in Figures 17A and 19A correspond to and are similar to those obtained for median CPI inflation in Figures 17 and 19 in the main text.

**Figure 17A. Scenarios for Core (Median) PCE Inflation Conditional on September 2022 FOMC Unemployment Forecasts**
(12-month; percent)




Note: Unemployment forecast from the Summary of Economic Projections of the Federal Open Market Committee (FOMC) published in September 2022 which provides numbers for the fourth quarters of 2022, 2023, 2024, and 2025. We assign those forecasts to November of each year and interpolate a monthly unemployment series starting from the actual value of 3.5 percent in September 2022. Vertical line indicates September 2022. Core inflation denotes PCE median inflation. Horizontal dashes indicate assumed 2.4 percent target for median PCE inflation based on 2 percent PCE target and 0.4 percentage point gap between the median PCE inflation and PCE inflation excluding food and energy following approach on Federal Reserve Bank of Atlanta Underlying Inflation Dashboard.

**Figure 19A. Scenarios for Core (Median) PCE Inflation Conditional on Alternative Unemployment Paths**
(12-month; percent)




Note: Vertical line indicates September 2022. IMF staff forecast for the quarterly path of unemployment underlying the October 2022 IMF *World Economic Outlook* Report. Quarterly forecasts are allocated to the second month of each quarter and a monthly path is obtained via interpolation. "Higher unemployment" path assumes 7.5 percent unemployment during 2023 and 2024 as suggested by Summers (2022b). In this scenario, the unemployment rate rises linearly from its September 2022 level to 7.5 percent in January 2023 and remains at that level through December 2024. Horizontal dashes indicate assumed 2.4 percent target for median PCE inflation based on 2 percent PCE target and 0.4 percentage point gap between the median PCE inflation and PCE inflation excluding food and energy following approach on Federal Reserve Bank of Atlanta Underlying Inflation Dashboard.