NBER WORKING PAPER SERIES

UNDERSTANDING U.S. INFLATION DURING THE COVID ERA

Laurence M. Ball
Daniel Leigh
Prachi Mishra

Working Paper 30613
http://www.nber.org/papers/w30613

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
October 2022

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, Aysegul Sahin, 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 in this paper are those of the author(s) and do not necessarily represent the views of the IMF, its Executive Board, or IMF management. A draft version of this paper was presented at the Brookings Papers on Economic Activity (BPEA) Fall 2022 conference held in September 2022; and the final version of this paper will be published in the Fall 2022 BPEA issue. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

Understanding U.S. Inflation During the COVID Era
Laurence M. Ball, Daniel Leigh, and Prachi Mishra
NBER Working Paper No. 30613
October 2022
JEL No. E31

ABSTRACT

This paper analyzes the dramatic rise in U.S. 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 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 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 Fed'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 Fed projects.

Laurence M. Ball
Department of Economics
Johns Hopkins University
Baltimore, MD 21218
and NBER
lball@jhu.edu

Prachi Mishra
IMF Research Department
700 19th Street NW
Washington, DC 20431
pmishra@imf.org

Daniel Leigh
International Monetary Fund
Research Department
700 19th Street, NW
Rm. 10-700N
Washington, DC 20431
dleigh@imf.org

A data appendix is available at http://www.nber.org/data-appendix/w30613

After four decades of low U.S. inflation, high inflation has emerged as a central economic problem of the COVID era. As of September 2022, the rate of CPI inflation over the previous 12 months was 8.2 percent. 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 non-core 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 1 of this paper describes how we measure core inflation. Our primary measure is the weighted median inflation rate published by the Federal Reserve 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 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 7.0 percentage points of the 8.2 headline inflation rate.

Section 2 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 (Ball and others, 2021a)—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 3 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 3 also performs a decomposition of the 6.9 percentage point rise in headline inflation between end-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 12-month inflation. A rise in expected inflation accounts for 0.5 percentage point, and the rise in labor market tightness (measured by the ratio of vacancies to unemployment) accounts for 2.0 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. Fed officials have predicted a soft landing in which inflation returns to their target with only a modest increase in unemployment, while pessimists such as Summers (2022b) believe that disinflation will require a painful recession with high unemployment. Which outcome is more likely?

In our view, the answer depends largely on two factors, which we discuss in Section 4. 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 5 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 Fed policymakers in their September 2022 Summary of

Economic Projections (SEP), which peaks at 4.4 percent in 2023 and 2024. 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 Fed'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.

1. HEADLINE AND CORE INFLATION

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

(1) headline inflation = core inflation + headline shocks .

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.

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. 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 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, 2021b).

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 (for example, Dolmas and Koenig, 2019; Verbrugge, 2021; and Ball and others, 2021b).[1]

This paper focuses on one specific outlier-exclusion measure of core, 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 Appendix to this paper considers other outlier-exclusion core measures, such as the trimmed mean 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. 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 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. See Ball and Mazumder (2011) for more on these ideas.

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

[1] 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.

median and deviations from median is a fruitful framework for understanding COVID-era inflation. We also show that much of our analysis would be infeasible if we measured core with XFE inflation.[2]

B. Headline and Core Inflation Since 2020

We focus here on inflation in the consumer price index (CPI); the Appendix considers the personal consumption expenditure (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). The graph on the left shows monthly inflation at seasonally adjusted annualized rates, and the graph on the right shows inflation over the past 12 months, a statistic that is widely reported in the media.

We can see from the Figure 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 12-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 12-month median was still below its level in January 2020. This experience, and the common view that non-core inflation movements are transitory, helps explain the insouciance about inflation among many economists when a handful such as Blanchard (2021) and Summers (2021) were first sounding an alarm. Since the middle of 2021, however, high monthly rates have led the 12-month median to follow headline inflation upward, and it reached 7.0 percent in September 2022.

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

[2] 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.

2. 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 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; 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 non-linearity 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 Recovery Act (the "Biden stimulus") 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 12-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.

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 Survey of Professional Forecasters (SPF). The Appendix considers another common measure, the five-year forecast from the 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.[3] We see that expected inflation has been stable. During 2000-2019 expected 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 Fed'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 Underlying Inflation Dashboard). 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 2019Q4 to 2.8 percent in 2022Q3. This rise presumably reflects the high realizations of actual inflation during this period. A vital question, which we discuss in Section 4, 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.[4] 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.

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

---

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

[4] 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.

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' Job Openings and Labor Turnover Survey (JOLTS), and Barnichon's (2010) extension of this data back to the 1950s using the help-wanted index from the Conference Board. We follow this approach.[5]

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 and Pissarides, 1999). In addition, there is some evidence from the pre-pandemic era that V/U out-performs 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 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) and not far below the Congressional Budget Office's estimate of the natural rate of unemployment (4.4), so by that measure the labor market has not been especially tight. 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 4.)

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 Cleveland Fed

[5] Long ago, Medoff and Abraham (1981) 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.

median series begins.[6] 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 11 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 Appendix considers the relation between the inflation gap and the current level of V/U alone).

Figure 3 shows quarterly and monthly scatter plots 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 era of 2020-2022 (through 2022 Q3 or September).[7]

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 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 grey squares on the right sides of the graphs. That was the last

[6] Some data details: We splice the Cleveland Fed's old and new series for the median following Ball and Mazumder (2011). Data for long-term (10-year-ahead) CPI inflation expectations come from the Philadelphia Fed website starting in 1979Q4. These data come from the Survey of Professional Forecasters starting in 1991Q4 and from Blue Chip semiannual survey data from 1979Q4 to 1991Q1 (with interpolation in between surveys). For 1968Q1 - 1979Q3, we use forecasts from the FRB/US dataset on the Fed website, which are constructed from a mixture of surveys and econometric work. These forecasts are for PCE deflator inflation; we add 0.4 percentage point to obtain CPI inflation forecasts, following a rule of thumb that the Fed staff used in constructing the dataset. In our monthly analysis, we use quarterly forecasts for the middle month of each quarter and interpolate between these months.

[7] 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.

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 scatter plots, 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 bandwith of 0.8, which produce similar results. The data suggest a fairly flat relation for mid-range 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 2, 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.

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 slack and assume implicitly that the evolution of core is unrelated to the deviations of headline from core (for example, Ball and others, 2021a). 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.

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 the production of other goods, so the price changes affect costs of production. Research at the European Central Bank, such as ECB (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 minus core inflation over the same four-quarter or 12-month period over which we measure V/U in the analysis above. This approach is consistent with ECB work on oil shocks, which finds that they transmit into inflation slowly. In the 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 12-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 has fallen to 1.4 percentage points as of September 2022.

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 12-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 non-linear. 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 passthrough effects from crude oil to retail fuel prices ("rockets and feathers").[8] 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 non-traditional 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.

[8] See, for example, Borenstein, Cameron, and Gilbert (1997) and Owyang and Verman (2014).

For both samples, the squared and cubic terms are statistically significant for both V/U and H: the data indicate non-linearity in the effects of these variables.[9] 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 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 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, Again Once again, our choice of a core inflation measure is critical for our results. The Appendix reports a version of the regressions in Table 1 with core

[9] In one case, monthly data for 1985-2019, the joint significance of the (V/U) squared and (V/U) cubed 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 ($p < 0.01$).

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.

E. The Role of the American Rescue Plan

Many economists and politicians blame the American Rescue Plan 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 the Ramey and Zubairy (2018) methodology 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 (Congressional Budget Office, 2020). Barnichon, Oliveira, and Shapiro 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.

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 12-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 12-month core inflation from end-2020 to September 2022 and about one quarter of the rise in 12-month headline inflation.

A caveat: we have assumed that labor-market tightness is the only channel through which the ARP has affected inflation. Summers (2022a) 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. To the extent that such effects are present, our estimate of the ARP's effects on inflation should be interpreted as a lower bound.

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 (ECI), a quarterly measure commonly used in previous work.

Figure 9 shows a scatter plot of the wage-inflation gap—wage inflation minus expected inflation—against the four-quarter average of V/U for the period 1968-2022Q2. 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).[10]

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 non-farm business sector smoothed with the Hodrick-Prescott filter with $\lambda = 16{,}000$). We present the estimated equations in the 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 super-impose the relations between median price inflation and the two variables (estimated here with quarterly data). We find that the effects of V/U and H on wage

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

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 non-linearities with noisy wage data.

3. 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.

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 the first Figure of this paper.

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 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-squared 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 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-squared 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 ten-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.[11]

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 12-month headline inflation rate in

[11] 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 Appendix).

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 point difference between these two inflation rates. Over the same period, 12-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 our preferred equation for headline shocks (column (3) of Table 2B) 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.[12]

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 point rise in 12-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 point.

The contribution of V/U to the rise in 12-month inflation is 2.0 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

[12] The details of our calculations are the following: 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 2B, Column 3) and the 12-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 12-month inflation change shown in Figure 12. We report a single residual that combines the residuals from the different steps in our calculations.

of 6.4 percentage points, from 1.9 percent to 8.3 percent), the contribution of V/U is 5.0 percentage points.

C. Why Has High Inflation Been Such a Surprise?

As inflation began to rise in March 2021, Fed Chair Powell predicted that the increase would be "neither particularly large nor persistent." (Powell, 2021a). At the Jackson Hole conference that August, Powell remained sanguine, noting "the absence so far of broad-based inflation pressures." (Powell, 2021b). Powell's view was supported by the many economists on Krugman's (2021) "Team Transitory," including the authors of this paper (Ball and others, 2021a). Today, it is clear that inflation was much higher than we expected.

What accounts for these forecasting errors? One factor is 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.[13]

First, economists measured labor market tightness with the deviation of unemployment from its natural rate, typically as estimated by the Congressional Budget Office. As a result, they neglected the tightening of the labor market captured by the dramatic increase in the job vacancies-to-unemployed ratio, although this was unexpected and did not occur until late 2021.[14]

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. Ball and others (2021a), 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,

[13] The analysis here overlaps with Furman (2022).

[14] 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.

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 12-month deviation of unemployment from the natural rate (as estimated by the Congressional Budget Office) 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 Appendix.) We see again that our preferred core-inflation equation performs well, as shown by the predicted path in short dashes with circles. We also see that the traditional equation with only a linear unemployment term performs quite poorly: it predicts a decrease in inflation in 2020 and almost no increase since then, reflecting the fact that the 12-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 the Figure 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.[15]

Today we can see that, even before the pandemic, inflation equations fit the data better with tightness measured by a non-linear function of V/U than with a linear function of U, and with a pass-through effect (see 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-

[15] The 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 under-prediction since May 2022); and the measure of slack, non-linearity, and the pass-through variable are all important.

market tightness that has made non-linearity obvious. Headline inflation shocks were smaller and less persistent than they have been since 2020, making the pass-through effect easy to miss.[16]

4. 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 is 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.

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 unemployment rates close to pre-pandemic levels along with very high vacancy rates.[17]

---

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

[17] 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.

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

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 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, so 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 and the Federal Reserve's Figura and Waller (2022) about prospects for the labor market. Figura and Waller 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 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:

(2) $v = au^b, \quad a>0, \quad b<0,$

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

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

If we substitute this expression for V/U into 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 tradeoff 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.[18]

We derive this tradeoff for two versions of the Beveridge curve: the ones estimated for the pre-pandemic period (dark line in Figure 14) and the pandemic period (light-colored line). 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.[19]

Figure 15 shows the results for the two Beveridge curves. A feature that jumps out in both cases is a striking non-linearity: 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 (for example, 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 tradeoff is steeper when unemployment is low. In our framework, this non-linearity has two sources corresponding to the two relations from which the curves are derived. First, as seen in Figure 6, V/U has a non-linear effect on inflation, with a large marginal effect when V/U is high. Second, V/U is strongly non-linear in U, with a large marginal effect when U is low. This second non-linearity 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 tradeoff 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 point 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-

[18] 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.

[19] 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.

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

*The Natural Rate of Unemploymen*t 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 by an average of about 0.20 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 0.20 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 0.20.

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 (the dark curve in Figure 15), and 6.5 percent for the pandemic-era Beveridge curve (the light 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 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 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.[20]

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 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 Fed 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 tradeoff 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 Survey of Professional Forecasters has risen from 2.2 percent in 2019Q4 to 2.8 percent in 2022Q3. Five-year expectations in the Michigan survey of consumers have risen from 2.2 percent in December 2019 to 2.9 percent in September 2022.

Will these modest increases in expected inflation be reversed as the Fed 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. (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.)

A Simple Model of Inflation Expectations We posit a simple equation in which expectations evolve in response to movements in headline inflation:

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

[20] 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.

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

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

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

We estimate γ 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 π_t (the first term in the summation) with the current-period (SPF) expectation of π_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:

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

We estimate γ, the single parameter in this equation, with non-linear 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 γ for each period, and the associated fitted values for expected inflation. Our results and interpretation for the four periods are the following:

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

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

5. 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 Fed 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 in their most recent (September 2022) Summary of Economic Projections (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 IMF's October 2022 *World Economic Outlook* in which unemployment peaks at 5.6 percent, and a much more pessimistic scenario suggested by Summers (2022b) in which unemployment rises to 7.5 percent for two years. Summers suggests that unemployment must rise that much to return inflation to the Fed'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.[21] 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.

A. Alternative Assumptions About the Beveridge Curve and Expectations

[21] 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 2020-2022.

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 (the light curve in 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 (the dark curve in Figure 14). Specifically, starting from the pandemic-era curve in July, the curve shifts one quarter of the way toward its pre-pandemic position every month, which means the outward shift during the pandemic is almost entirely reversed after about six months.[22]

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 2022Q3. We consider three scenarios for the evolution of expectations starting in October.

In our most optimistic scenario, confidence in the Fed'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: $\pi_t^e = \gamma\pi_{t-1}^e + (1-\gamma)\pi_t$ with γ = 0.980 at the quarterly frequency. We set γ equal to the cube root of 0.980 in our monthly simulations.

Finally, we consider a variation on the second scenario with γ = 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.

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:

[22] If v*(u) and v**(u) are the pre-pandemic and pandemic Beveridge curves, then the curve in October 2022 is (0.75)v**(u) + (0.25)v*(u). After October 2022, the curve in month t is $v_t(u)$ = (0.75)$v_{t-1}(u)$ + (0.25)v*(u).

- Use the Beveridge curve to derive V/U given the assumed U, and compute the 12-month average of V/U.
- Compute the 12-month headline shock H given zero monthly shocks starting in October 2022 and the actual shocks before that. The 12-month average declines to zero in September 2023.
- Given the 12-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 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).[23]

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 12-month path of core inflation. The 12-month path of headline inflation converges to core in September 2023.

C. Inflation Paths for the FOMC's Unemployment Forecasts

In considering possible paths for unemployment, a natural starting point is the forecasts of Fed policymakers, which are reported in the Summary of Economic Projections 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 Fed'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 12-month core (median CPI) inflation for the SEP unemployment path and our different Beveridge curve and expectations scenarios. Light-colored

[23] 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 π_{t-1}^e, we can solve the two equations for π_t and π_t^e.

lines are cases with the pessimistic Beveridge curve and dark lines indicate the optimistic Beveridge curve. The optimistic, middle, and pessimistic cases for expectations are shown in solid lines, dashes, and short dashes, respectively. 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 7.0 percent and peak at some point between December 2022 and July 2023, reflecting the fact that the 12-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.

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 point 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 Beveridge curve does not shift back, the inflation rate always stays above 4.0 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 non-inflationary level.

In interpreting these results, one nuance is that we forecast core inflation as measured by the weighted median CPI, whereas the Fed targets a two percent inflation rate in the personal consumption expenditure (PCE) deflator. According to the Federal Reserve Bank of Atlanta Underlying Inflation Dashboard, the Fed’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 Fed’s target. In all the other scenarios, however, inflation stays above the target.

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 Fed's inflation goal? To shed light on this question, we consider two other unemployment paths. One is based on unemployment forecasts for the U.S. in the IMF's *World Economic Outlook* of October 2022. These forecasts are more pessimistic than the Fed'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 (2022b) highly pessimistic suggestion that reversing the rise in inflation will require two years of 7.5 percent unemployment. 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 19A 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 Fed'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 19B 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 one percentage point away from that level. Our analysis suggests, therefore, that this scenario's unemployment path robustly brings inflation close to the Fed'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.

6. CONCLUSION

Yogi Berra observed that "it's tough to make predictions, especially about the future." This aphorism applies to the study of U.S. 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 12-month inflation between end-2020 and September 2022. A rise in expected inflation accounts for 0.5 percentage point, and the rise in labor market tightness (measured by the ratio of vacancies to unemployment) accounts for 2.0 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 Fed policymakers—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 Fed 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 non-linear 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.

References

Abraham, Katharine, John Haltiwanger, and Lea Rendell. 2020. “How Tight is the U.S. Labor Market?” *Brookings Papers on Economic Activity*, Spring, 97-165.

Barnichon, Regis. “Building a composite help-wanted index.” *Economics Letters* 109.3 (2010): 175-178.

Ball, Laurence, and N. Gregory Mankiw. 1994. “Asymmetric Price Adjustment and Economic Fluctuations.” *The Eonomic Journal*, 104 (March). 247–261.

Ball, Laurence, Gita Gopinath, Daniel Leigh, Prachi Mishra, Antonio Spilimbergo. 2021a. “US Inflation: Set for Take-Off?”, *VoxEU*. 07 May 2021.

Ball, Laurence, Daniel Leigh, Prachi Mishra and Antonio Spilimbergo. 2021b. “Measuring U.S. Core Inflation: The Stress Test of COVID-19", *NBER Working Paper*, 29609.

Ball, Laurence, and Sandeep Mazumder, 2021. "A Phillips Curve for the Euro Area," *International Finance*, Wiley Blackwell, vol. 24(1), pages 2-17, April.

Ball, Laurence, and Sandeep Mazumder. 2019. A Phillips Curve with Anchored Expectations and Short-Term Unemployment. *Journal of Money, Credit and Banking*, Vol. 51, No. 1.

Ball, Laurence, and Sandeep Mazumder. 2011. “Inflation Dynamics and the Great Recession.” *Brookings Papers on Economic Activity* 41 (1): 337–405.

Barnichon, Regis, Luiz E. Oliveira, and Adam H. Shapiro. 2021. “Is the American Rescue Plan Taking Us Back to the ’60s?”, *FRBSF Economic Letter*, 2021-27, October 18, 2021.

Barnichon, Regis. 2010. “Building a Composite Help-Wanted Index.” *Economics Letters* 109(3), pp. 175–178.

Barnichon, Regis and Adam Hale Shapiro. 2022. “What’s the Best Measure of Economic Slack?”, *FRBSF Economic Letter*, 2022-04 | February 22, 2022.

Bernanke, Ben S. 2004. “The Great Moderation.” Remarks by Governor Ben S. Bernanke at the *Meetings of the Eastern Economic Association*, Washington, DC. February 20, 2004

Blanchard, Olivier. 2021. “In Defense of Concerns over the $1.9 Trillion Relief Plan.” Real Time Economic Issues Watch, *Peterson Institute for International Economics*, Washington, DC.

Blanchard, Olivier. 2022. “Why I Worry about Inflation, Interest rates, and Unemployment”, *Peterson Institute for International Economics*, March 14, 2022.

Blanchard, Olivier, Alex Domash, and Lawrence H. Summers. 2022. “Bad News for the Fed from the Beveridge Space”, *Peterson Institute for International Economics Policy Brief* 22-7.

Bolhuis, Marijn A., Judd N. L. Cramer & Lawrence H. Summers, 2022, “Comparing Past and Present Inflation”, *NBER Working Paper* No. 30116, June 2022.

Borenstein, Severin, Colin A. Cameron, and Richard Gilbert. 1997. "Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes?" *Quarterly Journal of Economics* 112 (February 1997). pp. 305-339.

Briggs, Joseph, 2022, "The Beveridge Curve Debate: Has Match Efficiency Really Declined?", *US Economics Analyst, 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. University of Chicago Press.

Congressional Budget Office. 2020. "Key Methods That CBO Used to Estimate the Effects of Pandemic-Related Legislation on Output."

Crump, Richard K., Stefano Eusepi, Marc Giannoni, and Ayşegül Şahin, 2022, "The Unemployment-Inflation Trade-off Revisited: The Phillips Curve in COVID Times", *NBER Working Paper* No. 29785, February 2022.

di Giovanni, Julian, Ṣebnem Kalemli-Özcan, Alvaro Silva, and Muhammed A. Yildirim, 2022. "Global Supply Chain Pressures, International Trade, and Inflation." *NBER Working Paper* No. 30240.

Dolmas, Jim, and Evan F. Koenig, 2019, "Two Measures of Core Inflation: A Comparison," *Federal Reserve Bank of St. Louis Review*, Fourth Quarter 2019, 101(4), pp. 245-58.

Dolmas, Jim, 2005, "Trimmed Mean PCE Inflation," *Federal Reserve Bank of Dallas Research Department Working Paper* No. 0506.

Domash, Alex and Lawrence H. Summers (2022), "How Tight are U.S. Labor Markets?", *NBER Working Paper* 29739, February 2022.

European Central Bank, 2014, "Indirect Effects of Oil Price Developments on Euro Area Inflation", Box 3, Page 54. *Monthly Bulletin*, December.

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(S2), 355-391.

Figura, Andrew and Chris Waller, 2022, "What does the Beveridge Curve Tell Us About the Likelihood of a Soft Landing?", *FEDS Notes*, July 29, 2022.

Furman, Jason 2022, "America's Wage-Price Persistence Must Be Stopped", *Project Syndicate*, August 2, 2022.

Furman, Jason, and Wilson Powell III, 2021, "What is the Best Measure of Labor Market Tightness?", *Peterson Institute for International Economics*, November 22, 2021

Gagnon, Joseph E. and Christopher G. Collins, 2019, "Low Inflation Bends the Phillips Curve", *Peterson Institute for International Economics Working Paper* No. 19-6, April 2019.

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

Hazell, Jonathon, Juan Herreño, Emi Nakamura and Jón Steinsson, 2022. "The Slope of the Phillips Curve: Evidence from U.S. States," *The Quarterly Journal of Economics*, vol 137(3), pages 1299-1344.

Hilscher, Jens and Raviv, Alon and Reis, Ricardo A.M.R., How Likely Is an Inflation Disaster?, 2022. (April 26, 2022). Available at *SSRN*: https://ssrn.com/abstract=4083404 or http://dx.doi.org/10.2139/ssrn.4083404

Krugman, Paul, 2021, "Wonking Out: I'm Still on Team Transitory," *New York Times*, September 10.

Medoff, James L., and Katherine G. Abraham, "Unemployment, Unsatisfied Demand for Labor, and Compensation Growth in the United States, 1956-1980," in Martin Baily (ed.), *Workers, Jobs, and Inflation*, The Brookings Institution, 1982.

Mortensen, Dale T. and Pissarides, Christopher. 1999. "Job Reallocation, Employment Fluctuations and Unemployment." In: Taylor, John B. and Woodford, Michael, (eds.) *Handbook of Macroeconomics*. North-Holland. ISBN 9780444825285

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

Phillips, A.W. 1958. "The Relation Between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861–1957." (PDF). *Economica*, November 1958, Vol. 25, Issue 100, pp. 283-99.

Powell, Jerome. 2021a, "House Committee Hearing about the Coronavirus Aid, Relief, and Economic Security Act".

Powell, Jerome. 2021b. "Monetary Policy in the Time of COVID", At the "Macroeconomic Policy in an Uneven Economy," *Economic policy symposium* sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming, August 27, 2021.

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(2), pp. 850–901.

Reis, Ricardo. 2021. "Losing the Inflation Anchor", *Brooking Papers on Economic Activity*, September 9, 2021.

Staiger, Douglas, James Stock, and Mark Watson. 1997. "How Precise Are Estimates of the Natural Rate of Unemployment?" Chapter in *Reducing Inflation: Motivation and Strategy*, eds. Christina Romer and David Romer. Chicago: NBER and University of Chicago Press, pp. 195–246.

Summers, Lawrence H. 2022a. CNN of the interview of Summers by Fareed Zakaria on CNN, Aired July 24, 2022 - 10:00   ET, https://transcripts.cnn.com/show/fzgps/date/2022-07-24/segment/01

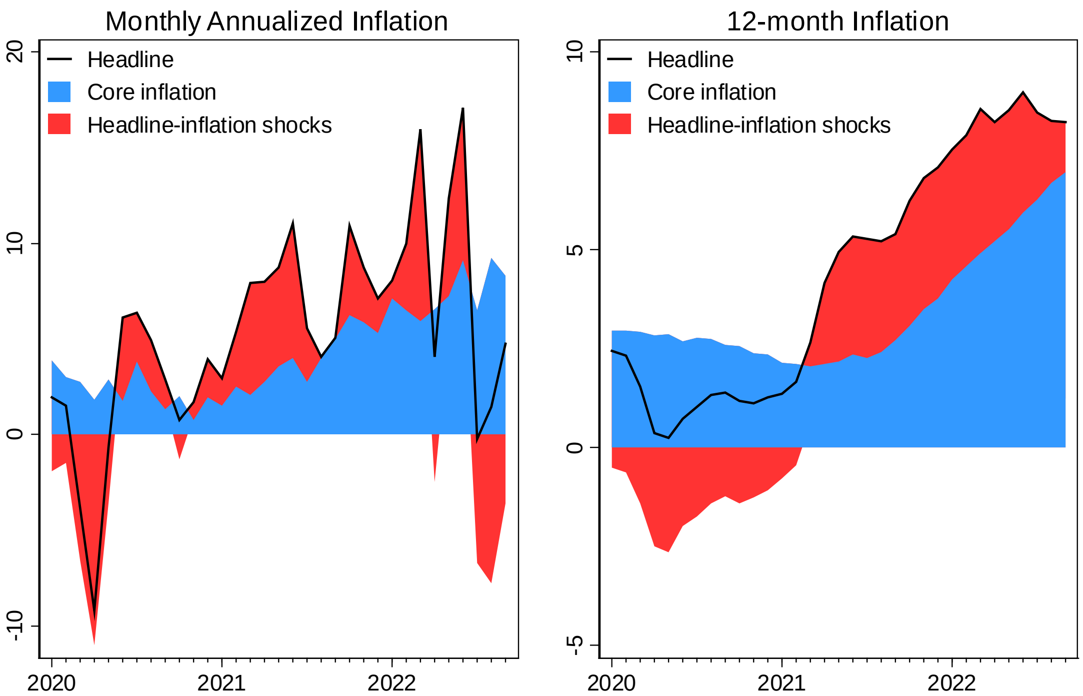
Summers, Lawrence H. 2022b. “Larry Summers Calls for High Unemployment to Curb Inflation”, *Fortune Magazine*, June 21, 2022

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

Verbrugge, Randal. 2021. “Is It Time to Reassess the Focal Role of Core PCE Inflation?” *Federal Reserve Bank of Cleveland Working Paper* No. 21–10.

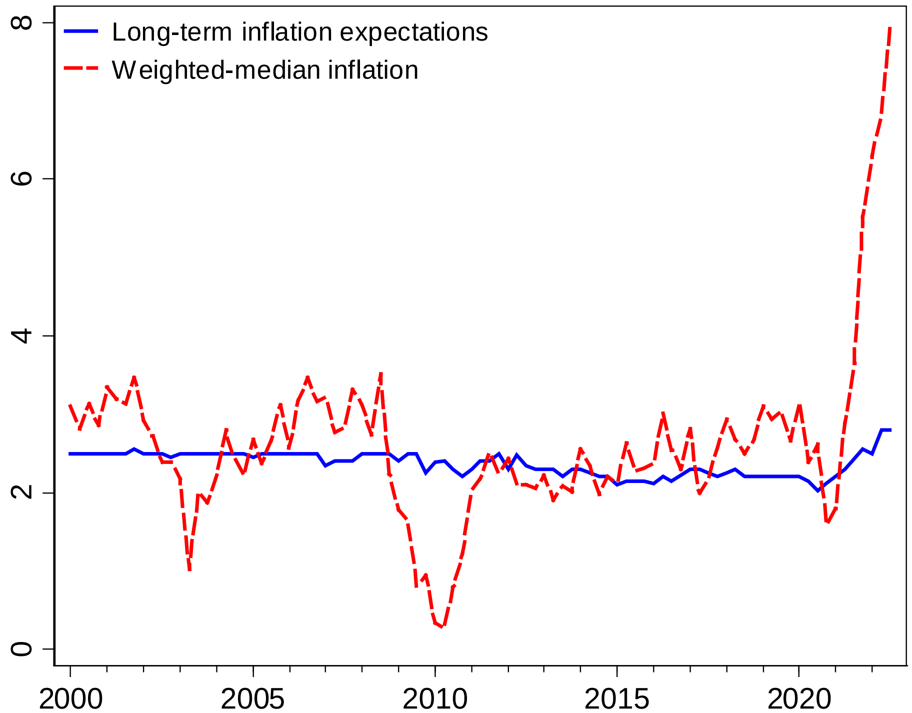
Yellen, Janet. 2019. “Former Fed Chair Janet Yellen on why the answer to the inflation puzzle matters.” Remark delivered at “What's (not) up with inflation?" event hosted by the *Hutchins Center on Fiscal and Monetary Policy at the Brookings Institution* on October 3, 2019.

Figure 1. CPI Inflation: Headline, Core, and Headline-inflation Shocks, 2020-2022



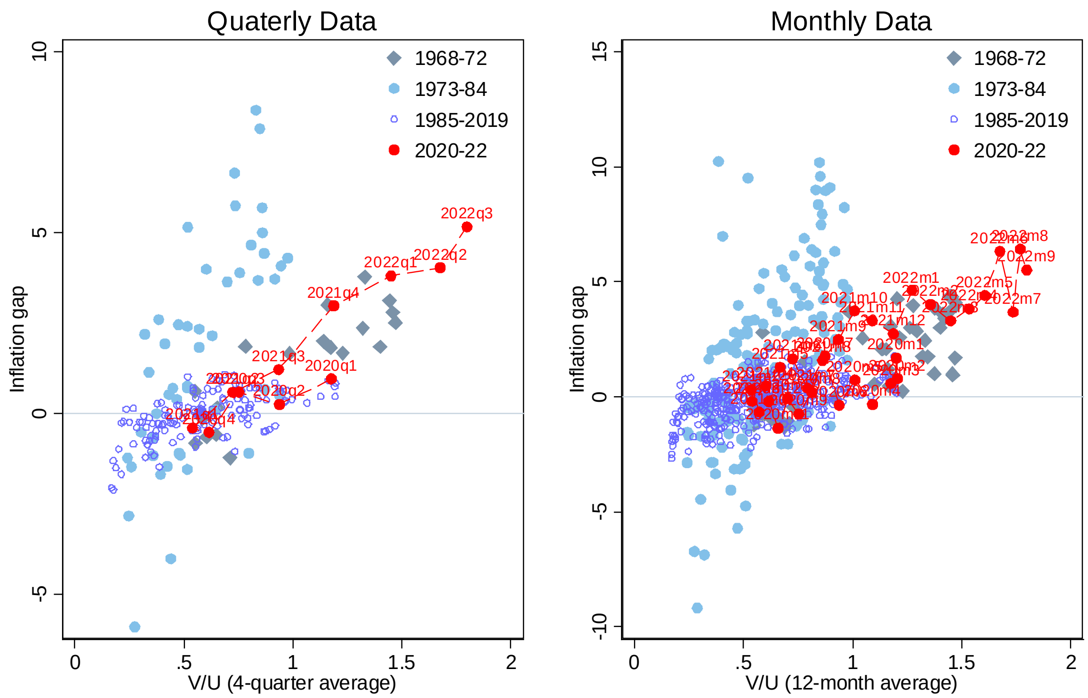
Note: Core inflation is median CPI inflation from the Federal Reserve Bank of Cleveland.

Figure 2. Long-term CPI Inflation Expectations and Median CPI Inflation, 2000-2022



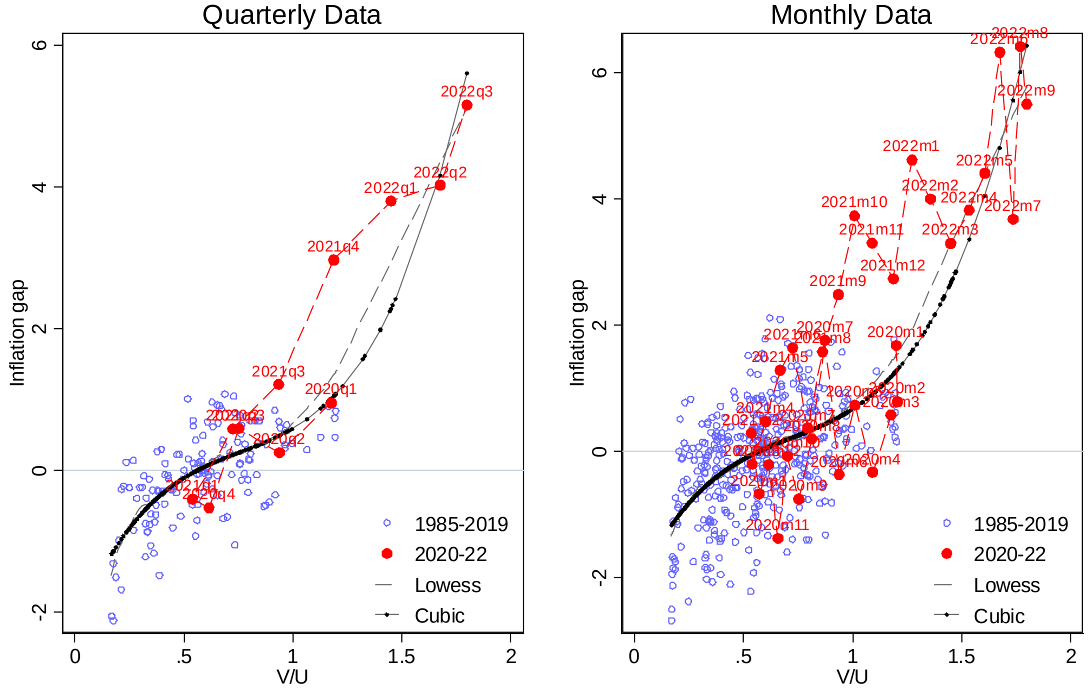
Note: Figure reports 10-year-ahead CPI inflation forecasts from the Survey of Professional Forecasters (SPF).

Figure 3. Inflation Gap vs. Ratio of Vacancies to Unemployed (V/U), 1968-2022



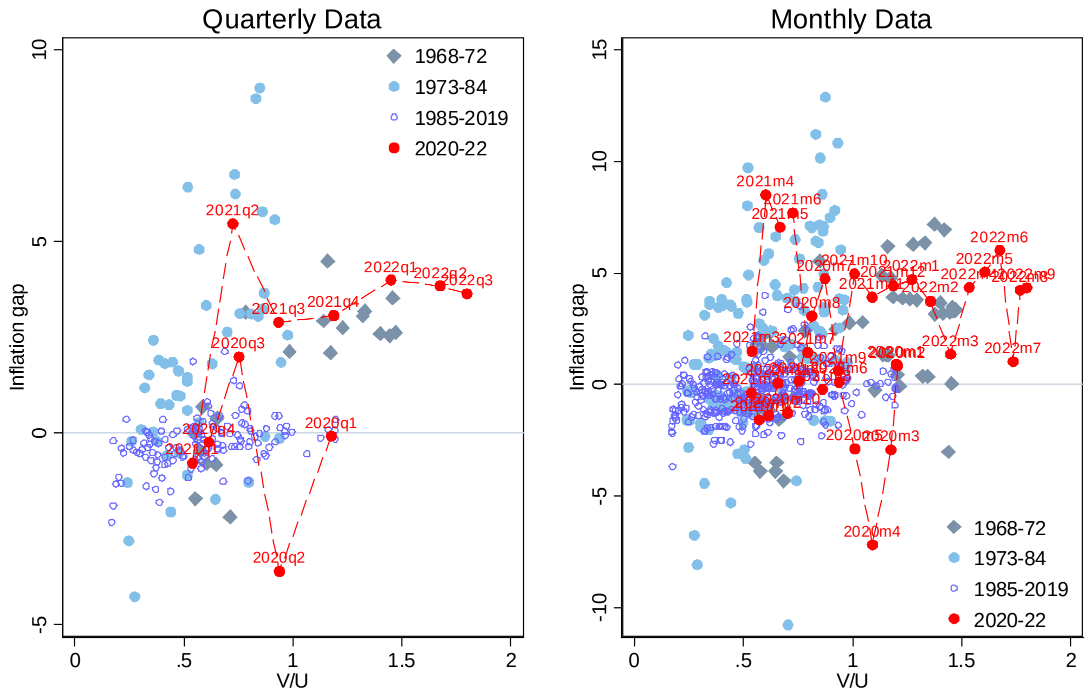
Note: Figure reports quarterly and monthly scatter plots of the inflation gap against the averages of V/U. Inflation gap is the difference between median and long-term expected inflation. Long-term expected inflation is the ten-year-ahead CPI inflation forecast from the Survey of Professional Forecasters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

Figure 4. Fitted Relationship: Inflation Gap vs. V/U, 1985-2022



Note: Figure 4 shows the results of fitting flexible curves to the data for 1985-2022. “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 from the Survey of Professional Forecasters. “V/U” denotes ratio of vacancies to unemployed (4-quarter or 12-month average).

Figure 5. CPI Inflation Excluding Food and Energy vs. V/U, 1968-2022



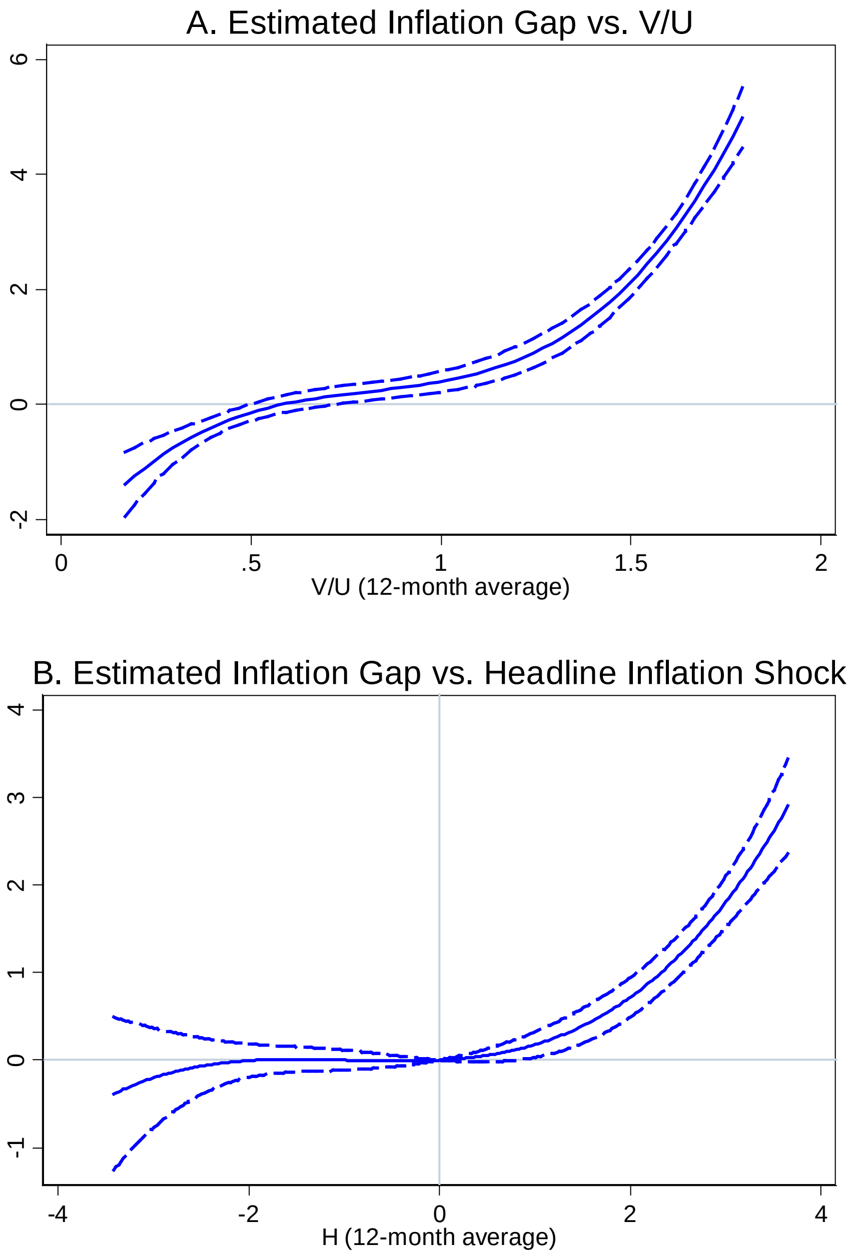
Note. Figure 5 repeats Figure 2, the scatterplots of the inflation gap against V/U, but with core inflation measured in the traditional way with inflation excluding food and energy prices (XFE). Inflation gap is the difference between XFE inflation and long-term expected inflation. Long-term expected inflation is the is the ten-year-ahead CPI inflation forecast from the Survey of Professional Forecasters (SPF). “V/U” denotes ratio of vacancies to unemployed (4-quarter or 12-month average).

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-squared	-13.261**	-10.083***	-10.879*	-10.328***
	(5.485)	(2.383)	(6.435)	(2.545)
V/U-cubed	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-squared	0.155***	0.081***	0.128***	0.089***
	(0.041)	(0.016)	(0.035)	(0.019)
H-cubed	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-squared	0.512	0.761	0.284	0.575
Rbar-squared	0.490	0.751	0.274	0.569

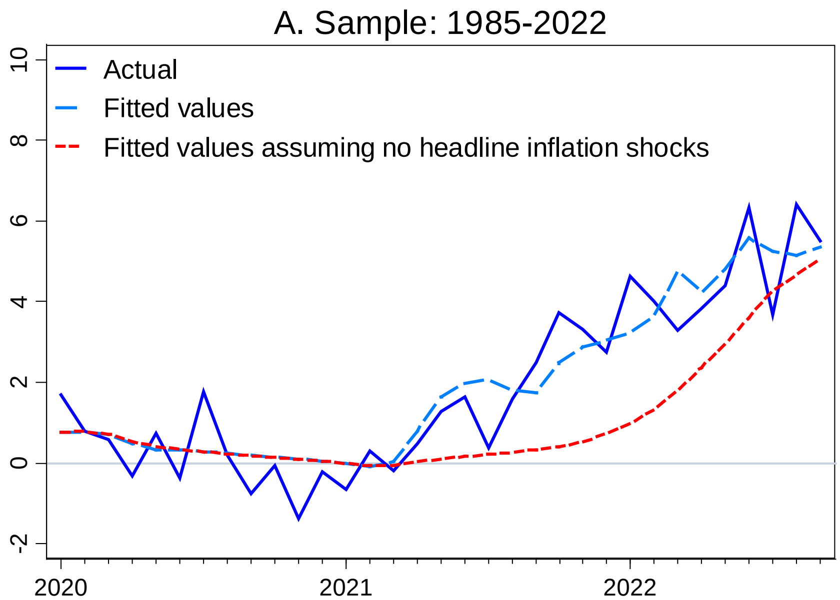
Notes: V/U denotes ratio of vacancies to unemployed (4-quarter or 12-month average). H denotes headline-inflation shock (4-quarter or 12-month average). Newey-West standard errors with 4 lags (quarterly data) and 12 lags (monthly data) in parentheses. ***, **, and * denote statistical significance at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

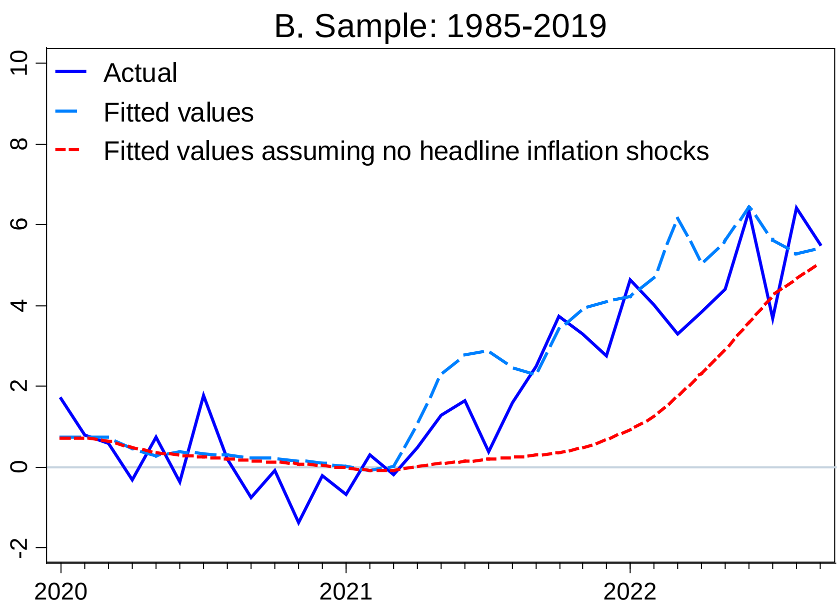
Figure 6. Estimated Inflation Gap as a Function of Slack and Headline-inflation Shocks, 1985-2022
(Percentage points; monthly data)



Note: Panel A reports fitted values for constant term and V/U terms from equation estimates reported in Table 1 (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 long-term Survey of Professional Forecasters inflation expectations.

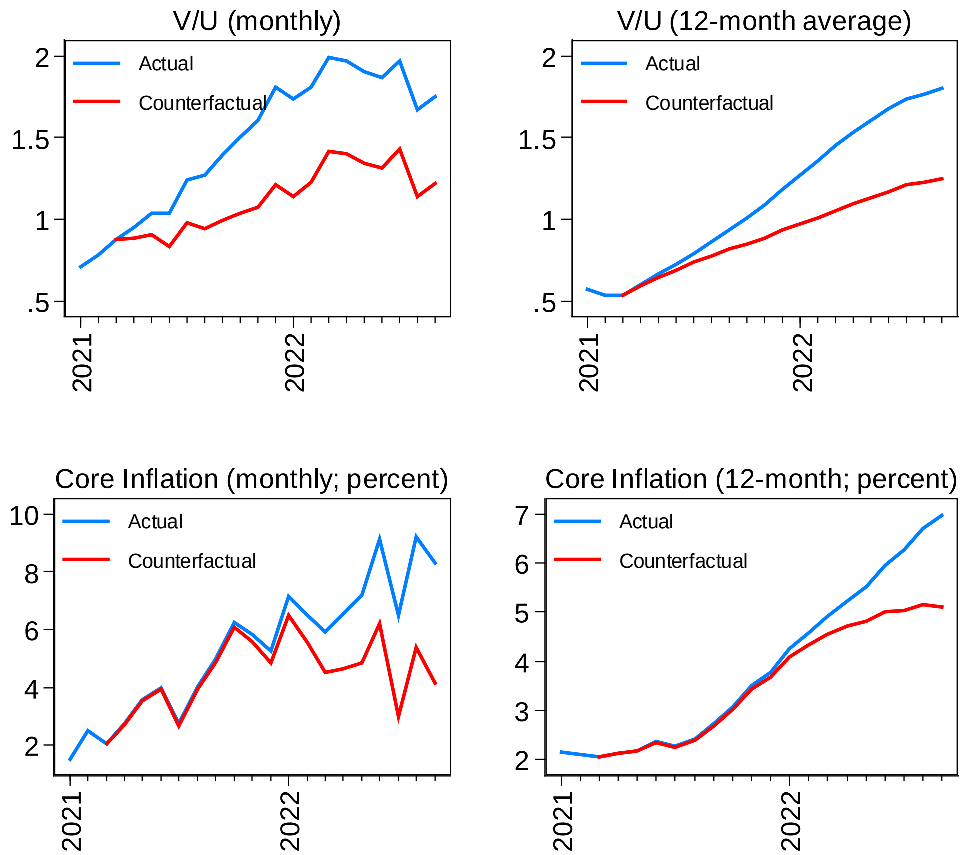
Figure 7. Predictions for Median Inflation Gap During, 2020-2022
(Percentage points)





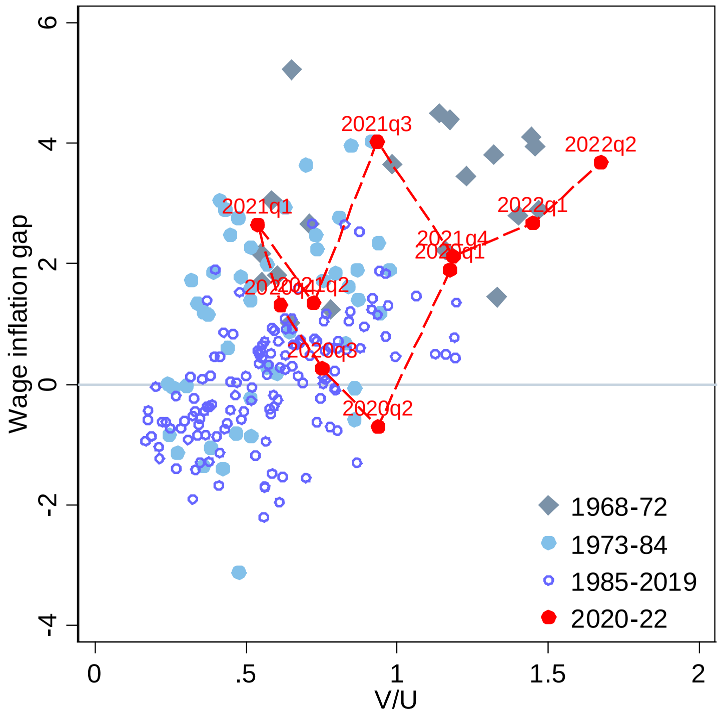
Note: Figure reports fitted values from Phillips Curve model estimated for the full sample (Table 1 column 4) and for the pre-pandemic sample (Table 1 column 3). Inflation gap denotes monthly annualized median CPI inflation minus long-term Survey of Professional Forecasters inflation expectations.

Figure 8. Counterfactual Scenario Without American Rescue Plan



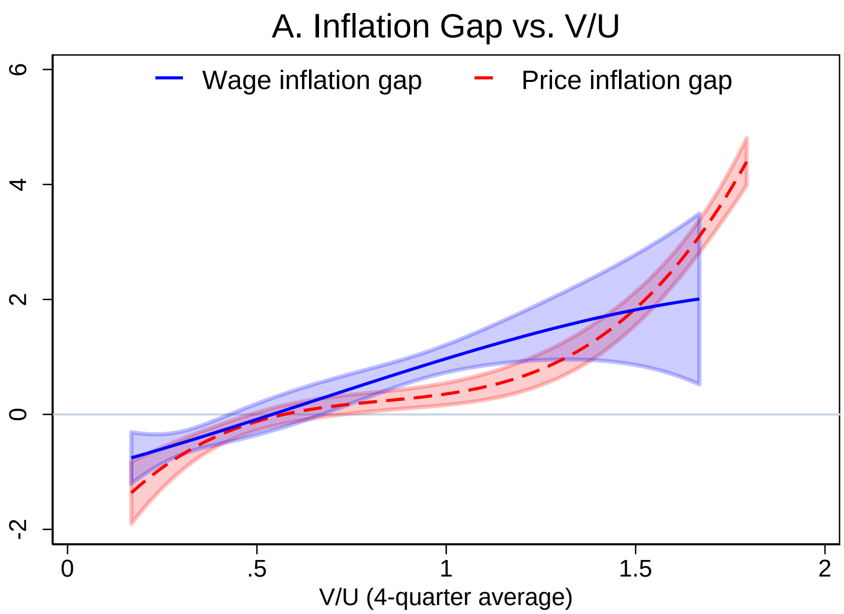
Note: Impact of American Rescue Plan on V/U comes from Barnichon, Oliveira, and Shapiro (2021). Core inflation denotes median CPI inflation. Monthly inflation is annualized. Impact on core inflation derived from Phillips Curve relation estimated for 1985-2022.

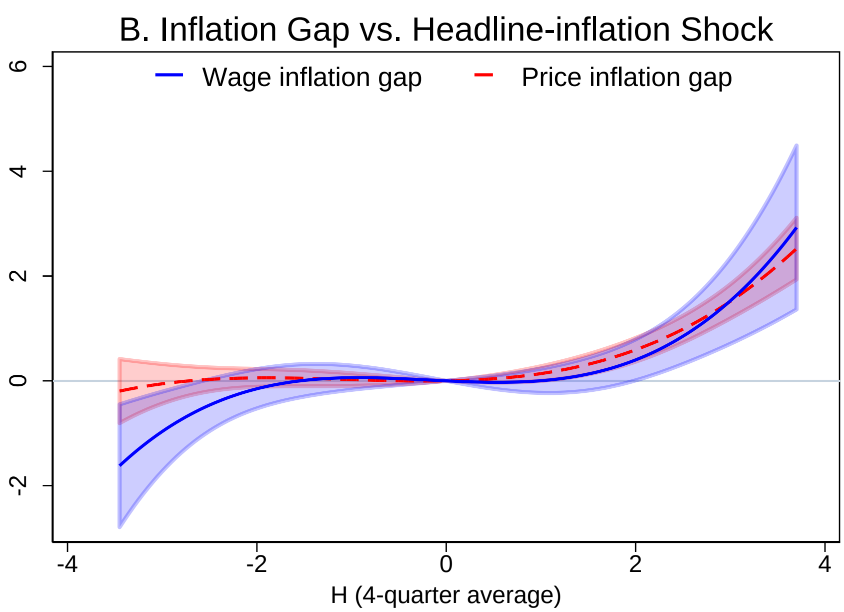
Figure 9. Wage Inflation Gap vs. Ratio of Vacancies to Unemployed



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 from the Survey of Professional Forecasters (SPF). "V/U" denotes ratio of vacancies to unemployed (4-quarter average).

Figure 10. Estimated Wage and Price Inflation Gaps as Functions of Slack and Headline-inflation Shocks, 1985-2022
(Percentage points; quarterly data)





Note: For price inflation, figure reports fitted values for constant and ratio of vacancies to unemployed (V/U) terms based on specification reported in Table 1 (column 2) in top panel and fitted values for headline-inflation shock (H) terms in bottom panel. For wage inflation, figure reports fitted values for constant, V/U and productivity growth terms based on specification reported in Annex Table 10 (column 2) with productivity growth set at its sample mean. Inflation gap denotes quarterly median CPI inflation or wage inflation minus long-term Survey of Professional Forecasters inflation expectations. Bands report 95 percent confidence interval.

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

A. Bivariate Regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Energy price inflation	Food price inflation	Harper Charter Rate	Baltic Dry	Supplier delivery times	FRBNY Supply Chain Index	Backlogs of work	Goods share of real consumption	Weighted average of car inflation rates	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-squared	0.657	0.041	0.026	0.216	0.138	0.043	0.447	0.277	0.216	0.019
Rbar-squared	0.646	0.0104	-0.00564	0.191	0.110	0.0125	0.429	0.253	0.191	-0.0127

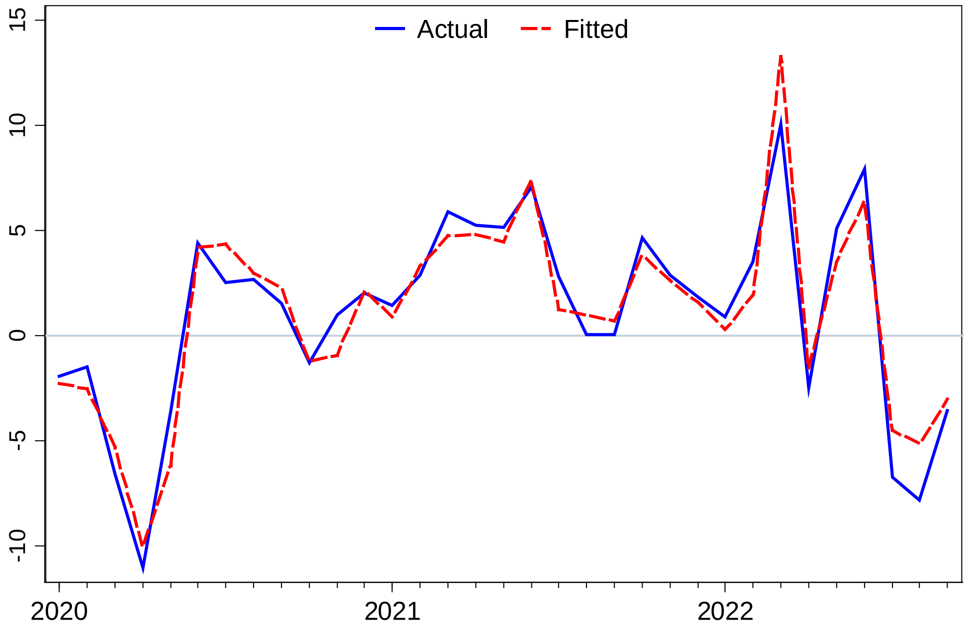
B. Selected Multivariate Regressions

	(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-squared	0.785	0.827	0.920	0.922
Rbar-squared	0.771	0.809	0.912	0.911

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. ***, **, and * denote statistical significance at the 1,5, and 10 percent level, respectively. We do not report Newey-West standard errors because they can be unreliable in a sample as short as ours.

Figure 11. Explaining Headline-inflation Shocks

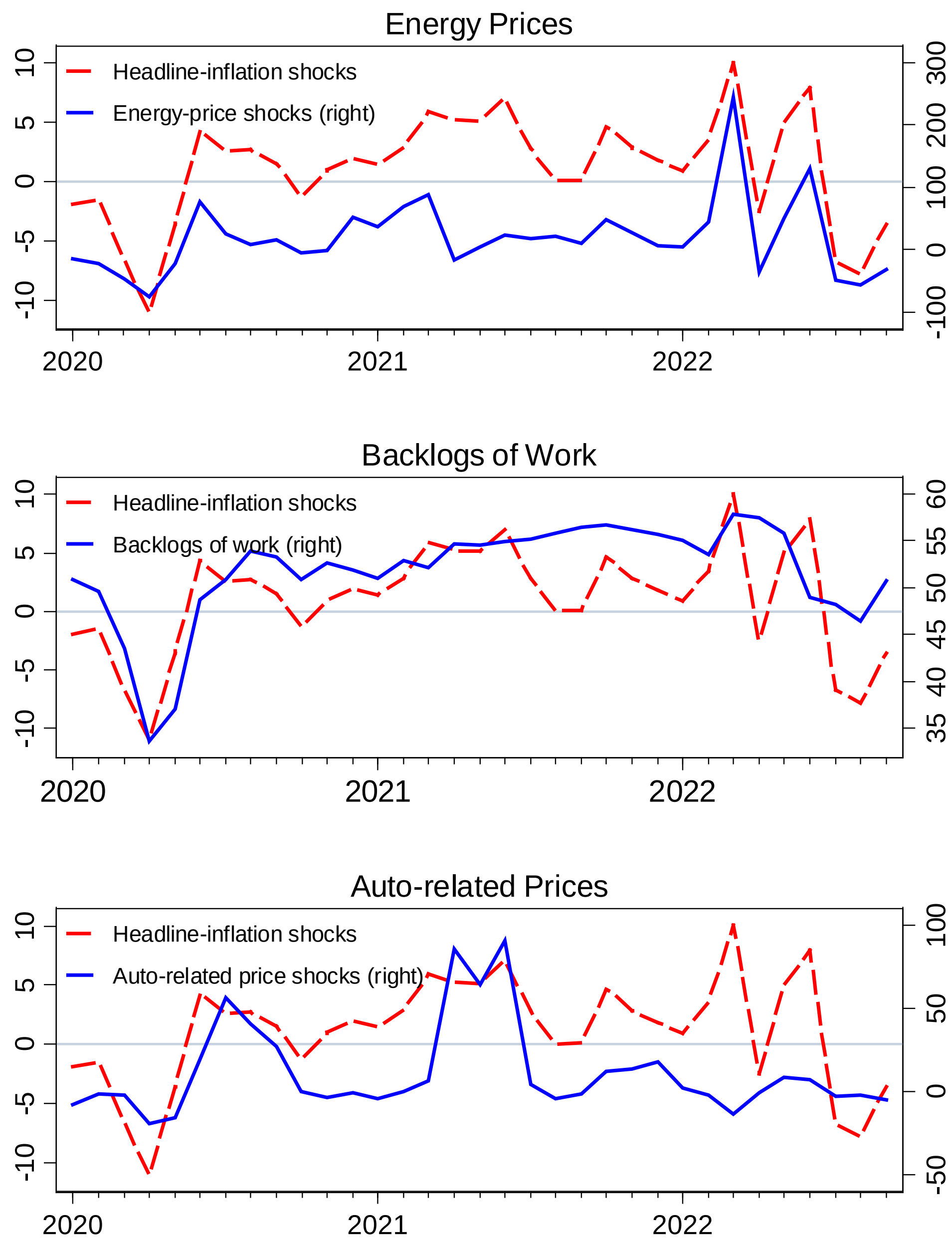
A. Actual vs. Fitted Values



Note: Headline-inflation shocks denote the difference between headline and median CPI inflation. “Fitted” denotes fitted values of headline-inflation shocks from the regression in Column 3, Table 2.

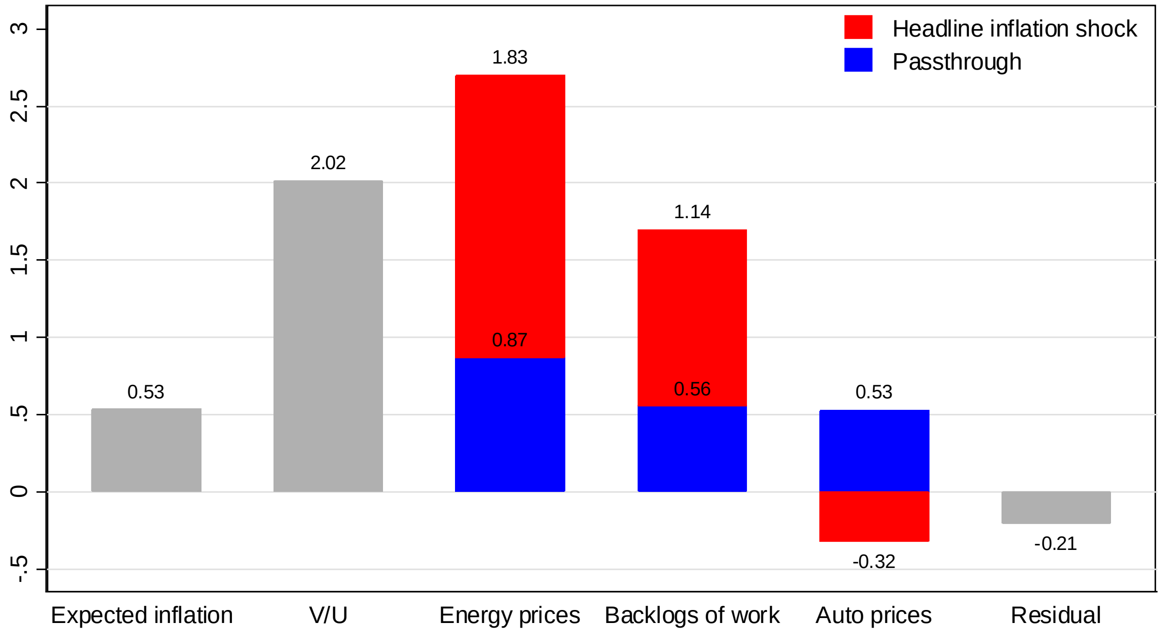
Figure 11. Explaining Headline-inflation Shocks (Continued)

B. Headline-inflation Shocks vs. Selected Variables



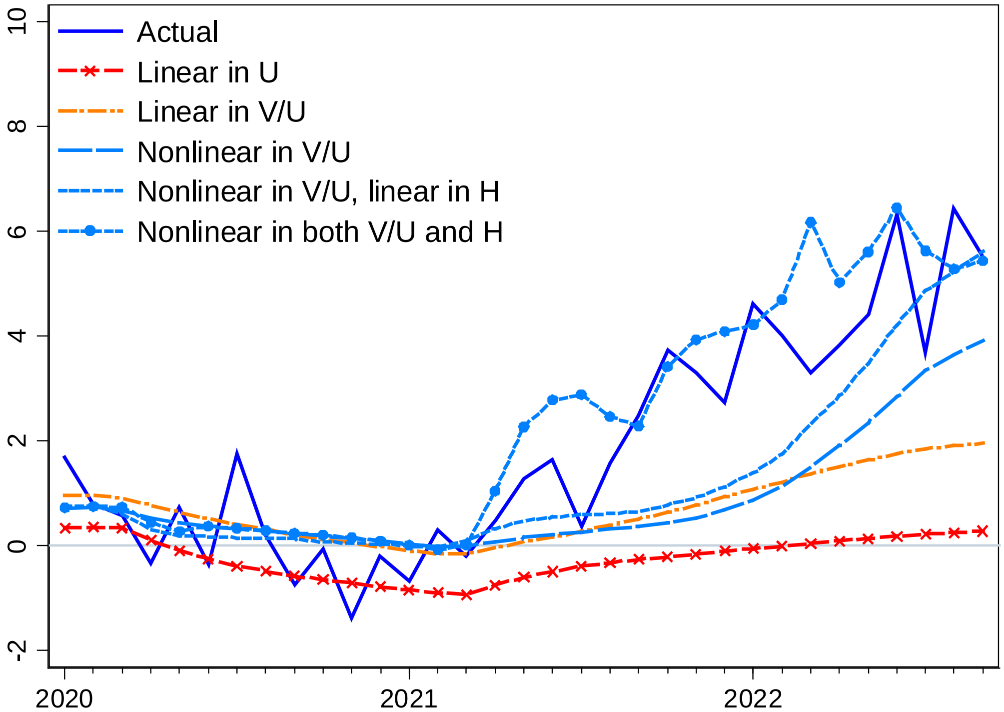
Note: Headline-inflation shocks denote the difference between monthly annualized headline and median CPI inflation. Energy and auto-related price shocks variables are created by subtracting median inflation from energy and auto-related price inflation, respectively. These variables are in monthly annualized terms. Backlogs of work variable is taken from IHS Markit Economics.

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)



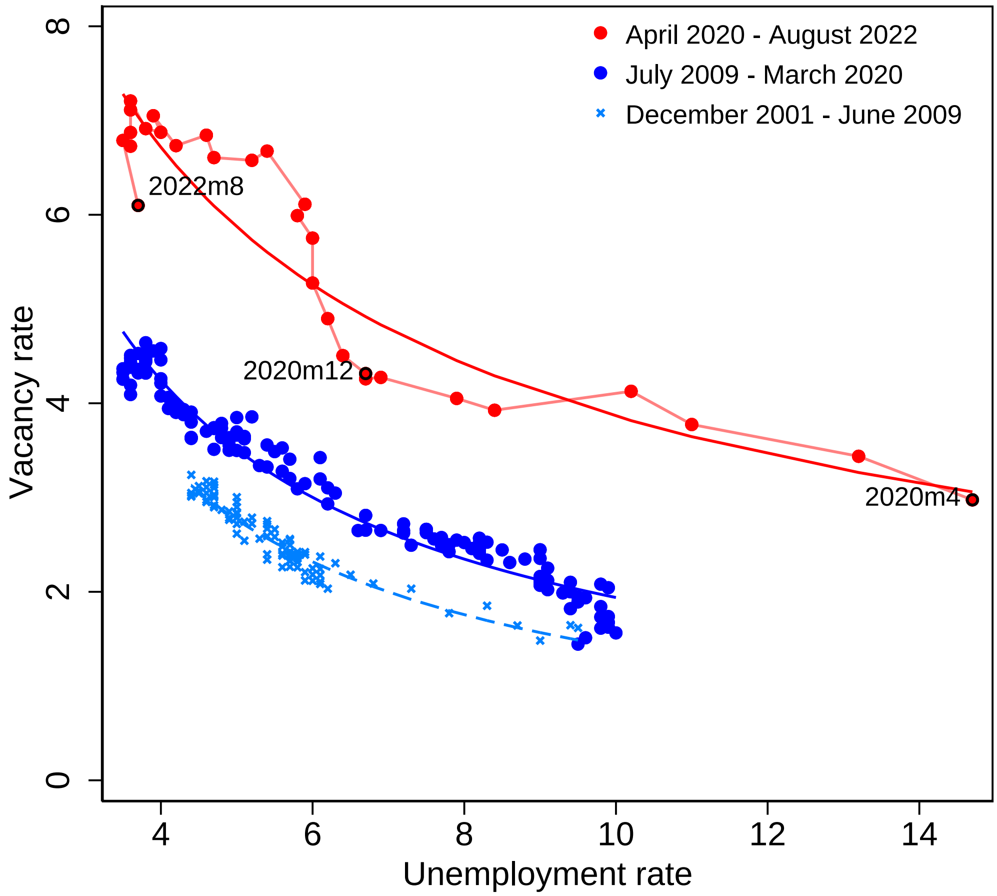
Note: Total rise in 12-month headline inflation is 6.94 percentage points (from 1.28 percent to 8.22 percent). The total rise in 12-month core (median) CPI inflation over this period is 4.63 percentage points (from 2.34 percent to 6.98 percent). “Expected inflation" denotes contribution of change in 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 2B (column 3).

Figure 13. Predictions for Median CPI Inflation Gap During the Pandemic: Comparison Across Models



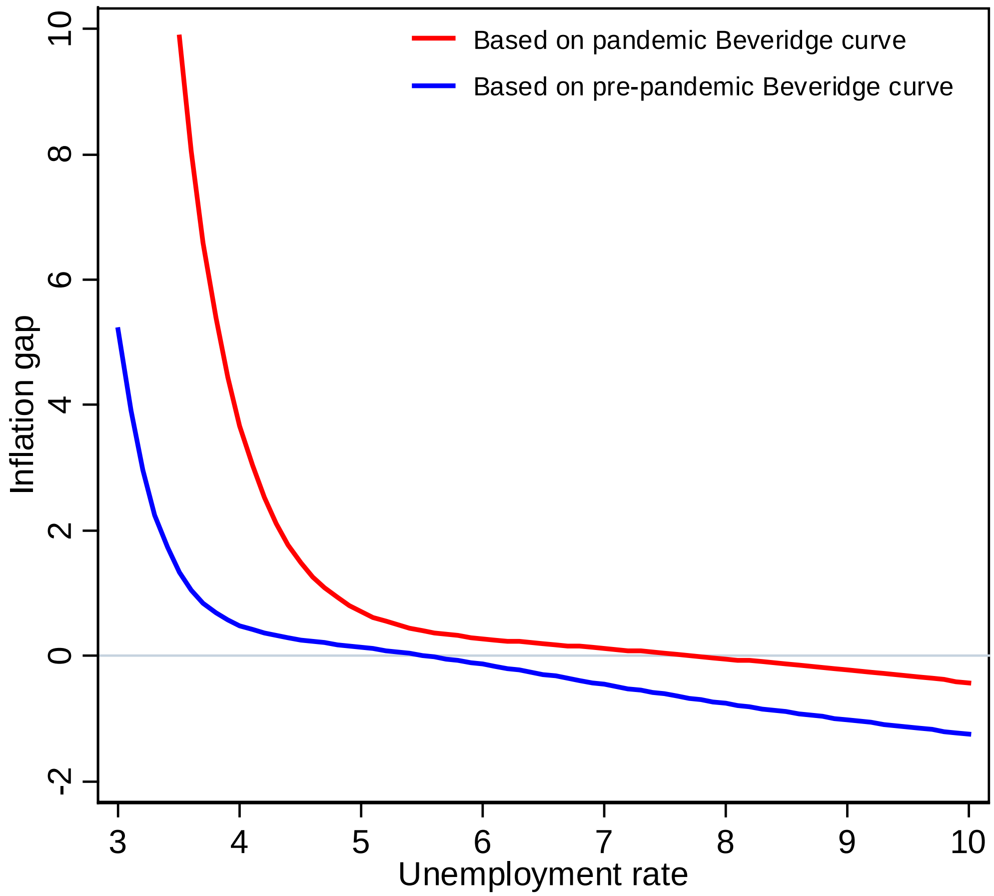
Note: Figure reports predicted values based on monthly equations estimated for 1985-2019 (Annex Table 13A). Our preferred core-inflation equation is shown by the predicted path in short dashes with circles. The predicted values from the traditional equation with only a linear unemployment (U) term is 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, non-linearity, and the pass-through variable (H)—contributes to the good fit of our final preferred equation.

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



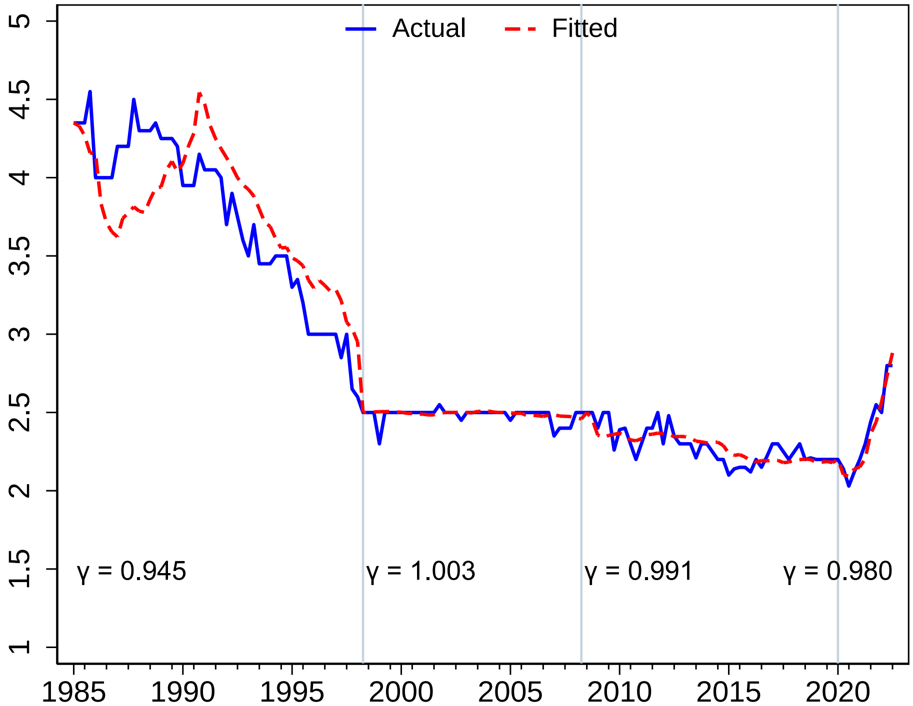
Note: December 2001 – June 2009 covers Great Recession and the preceding expansion, based on NBER business cycle dates. July 2009 – March 2020 covers the pre-COVID expansion and the first month of COVID era. Figure reports log-linear curves fitted to each period. Rates in percent of labor force.

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



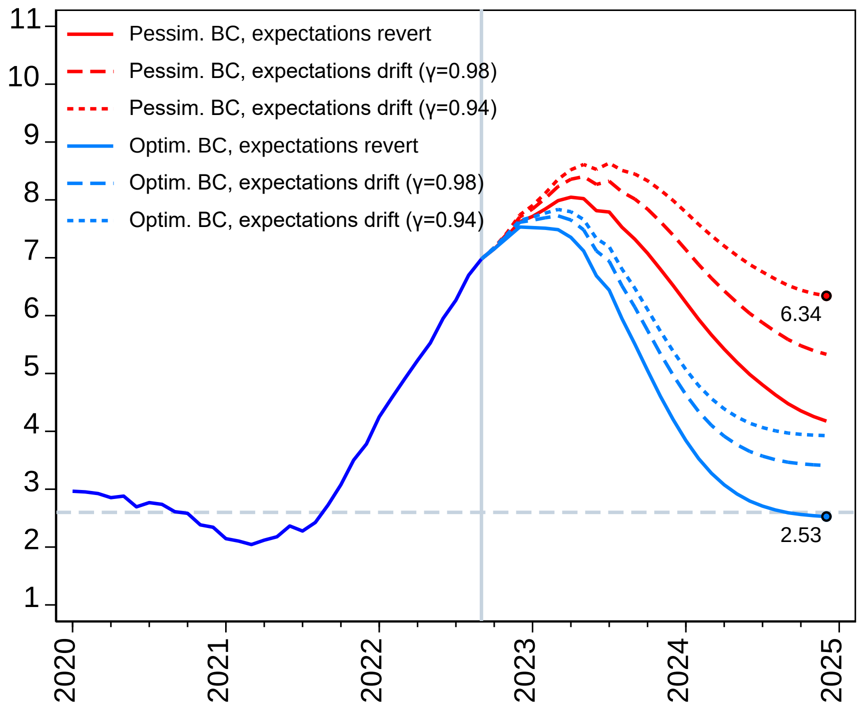
Note: Inflation gap denotes monthly annualized median CPI inflation minus long-term SPF inflation expectations. Curves are derived from the estimates of the Phillips curve (Table 1 column 4) and the Beveridge curves reported in footnote 21.

Figure 16. Actual and Fitted Inflation Expectations



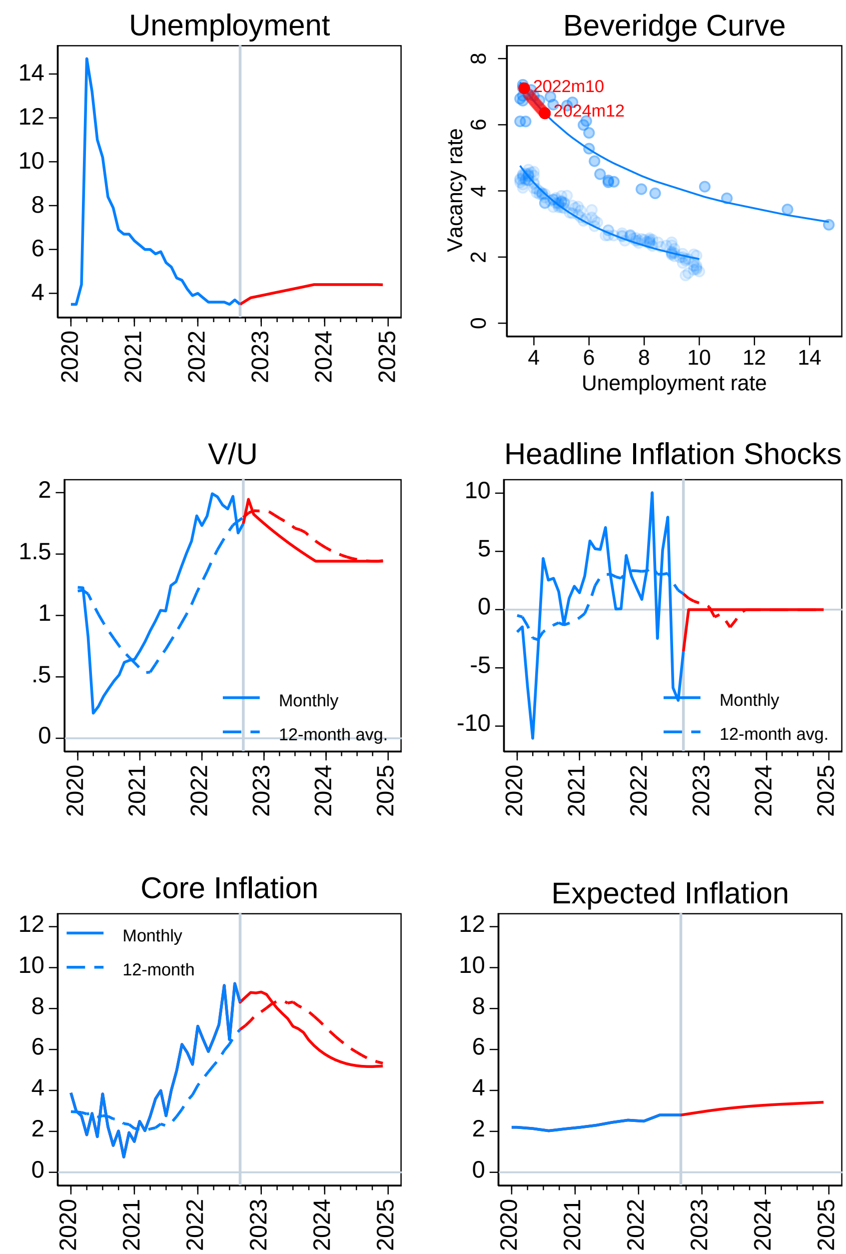
Note: Figure reports actual values of long-term CPI inflation expectations from the Survey of Professional Forecasters (SPF) and fitted values for several periods from the partial-adjustment model described in the text. The parameter γ indicates the degree of anchoring of inflation expectations in each period.

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



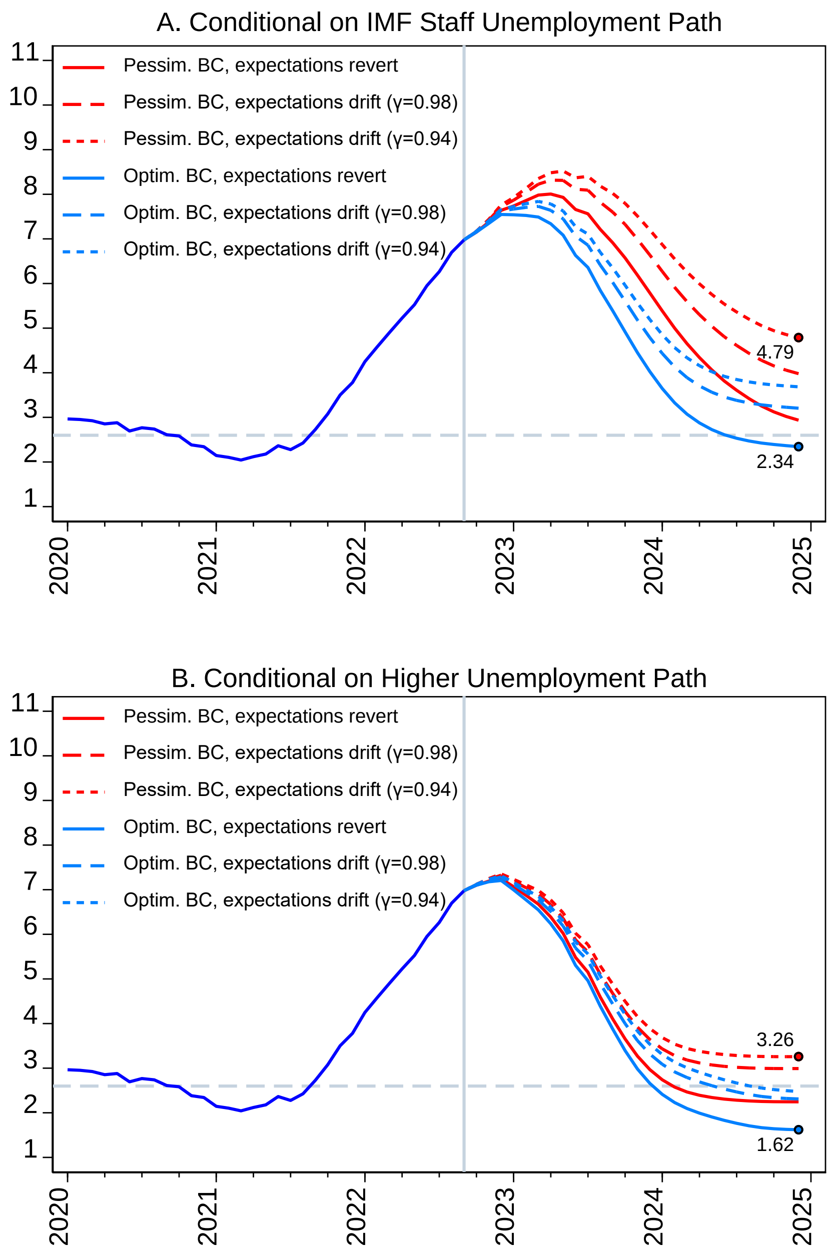
Note: Unemployment forecast from the Summary of Economic Projections of the Federal Open Market Committee (FOMC) published in September 2022 which provides numbers for the fourth quarters of 2022, 2023, 2024, and 2025. We assign those forecasts to November of each year and interpolate a monthly unemployment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

Figure 18. Scenario Conditional on September 2022 FOMC Unemployment Forecasts with Pessimistic Beveridge Curve and Drifting Expectations (γ = 0.98)



Note: Figure reports scenario with COVID-era Beveridge Curve and drifting expectations (γ = 0.98). Observations up to September 2022 in blue; projections thereafter in red. Core inflation denotes CPI median inflation.

Figure 19. Scenarios for Core CPI Inflation Conditional on Alternative Unemployment Paths
(12-month; percent)



Note: Vertical line indicates September 2022. Core inflation denotes CPI median inflation. 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 show 2.6 percent target for median CPI based on 2 percent PCE target reported on Federal Reserve Bank of Atlanta Underlying Inflation Dashboard.