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Managing Disinflations

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Managing Disinflations

Abstract

What do history and a simple model teach us about the prospects for central bank efforts to lower inflation to target from recent multi-decade highs? To answer this question, we start by analyzing the large disinflations that occurred since 1950 in the United States and several other major economies. Then, we estimate and simulate a standard model over several time periods, using various linear and nonlinear measures of labor market slack. We draw three main lessons from the analysis: (1) there is no post-1950 precedent for a sizable central-bank-induced disinflation that does not entail substantial economic sacrifice or recession; (2) regardless of the Phillips curve specification, models estimated over a historical period that includes episodes of high and variable inflation do a better job of predicting the post-pandemic inflation surge than those estimated over the stable inflation period from 1985 to 2019; and (3) simulations of our baseline model suggest that the Fed will need to tighten policy significantly further to achieve its inflation objective by the end of 2025. Going forward, our analysis supports a return to a strategy of preemptive policy. We also argue that raising the Fed's inflation target is a misguided alternative to incurring the sacrifice needed to achieve the 2 percent target.

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1. Introduction

The surge of inflation in 2021-22 surprised most major economy central banks. Over the past year, authorities responded with an unusually rapid, if belated, tightening of monetary policy. In the United States, according to the Summary of Economic Projections (SEP), the median participant at the final 2021 FOMC meeting anticipated policy tightening of 75 basis points over the following year. By the end of 2022, rate hikes totaled 425 basis points, an outcome that was a full 3 percentage points above the highest of the December 2021 participants' projections.

This dramatic shift in the stance of U.S. monetary policy came shortly after the FOMC retired the word "transitory" from its description of the inflation outlook. As the Committee's understanding of the nature of the current inflation episode evolved, so too did its view of the actions they would need to take to restore price stability. Rather than simply normalizing policy, as policymakers anticipated in late 2021, FOMC participants saw their task as "expeditiously" returning to a neutral stance and then moving on to an unmistakably restrictive one. By late 2022, expectations of the inflation and growth outlook had changed so much that the Committee broadly anticipated a period of gradual disinflation accompanied by a period of subpar economic performance.

For the vast majority of 21st century central bankers, managing a sizable disinflation is familiar only through historical records. Even now, most FOMC participants expect a benign return to price stability. As of the December 2022 SEP, few policymakers project any decline of real GDP or for the unemployment rate to rise as high as 5 percent. At the same time, several prominent outside analysts question the optimism of FOMC forecasts, pointing to the historical record of costly disinflations.[1] We examine this important divergence in view both by studying the historical record and using a simple three-equation model.

We begin the historical analysis by computing the sacrifice ratio—the increases in slack associated with reductions in inflation—for 17 large disinflationary episodes in the United States and other major advanced economies since 1950. Notable precedents for this approach include Ball (1994), who computes sacrifice ratios for a number of OECD countries during the 1960s, 1970s and 1980s, and Tetlow (2022), who surveys similar studies as well as sacrifice ratios simulated in 40 U.S. macro models.

Our results largely conform to those in the literature. That is, we find no instance in which a central-induced disinflation occurred without a recession. At the same time, we find that the cost of disinflation differs markedly across episodes. It also varies with both the starting point for inflation and the speed of disinflation. Specifically, the cost of reducing inflation by one percentage point is lower when the disinflation starts from a higher level, or when it proceeds more rapidly.

With these stylized facts in mind, we ask how policymakers can minimize the costs to employment and activity of a sizable disinflation. Any prescription will hinge on understanding the ever-evolving inflation process, especially the Phillips curve relationship between labor market slack and inflation that is traditionally the central element in characterizing the sacrifice ratio. To answer this question, we revisit the time-honored question about the relationship between unemployment and inflation. Specifically, we ask whether there is a version of the Phillips curve that can account for the behavior of inflation over

[1] See, for example, Lawrence Summers' comments in a June 2022 quote by Ansley (2022).

the past two years. For this purpose, we compare various specifications over different estimation periods.

Critically, we find that—*regardless of the specification*—Phillips curves estimated using information that includes the high and volatile inflation period *before* 1985 do a better job of anticipating the outsized inflation jump of 2022. Furthermore, Phillips curves using the full historical sample (1962-2022) exhibit a greater sensitivity to slack. In practice, however, inflation is far more sensitive to slack in a hot labor market than in a cold labor market.

We believe these findings have key implications for monetary policy and the role of preemption. For example, the view that inflation will revert to the Fed's 2 percent target without a sizable increase of slack is at least partly dependent on the experience during the stable inflation expectations period of the Great Moderation (1985-2019). However, even assuming stable inflation expectations, our analysis casts doubt on the ability of the Fed to engineer a soft landing in which inflation returns to the 2 percent target by the end of 2025 without a mild recession.

In our analysis, we modify the Phillips curve specification by introducing an alternative measure of labor market slack and a nonlinear functional form. On the first, we substitute the vacancies to unemployment ratio (v/u) in the place of the unemployment rate. The v/u ratio is a prominent measure of labor market tightness in modern labor market search and matching theory. Moreover, unlike the unemployment rate, it suggests the labor market is currently much tighter than it was at the end of the last expansion.

In addition, we introduce the v/u gap, which adjusts the v/u ratio for its changing noncyclical value (v/u^*), much as the unemployment gap adjusts the unemployment rate (u) for its noncyclical rate (u^*). Unlike v/u itself, the v/u gap takes account of shifts of the Beveridge curve (which links v and u), including the large outward shift that followed the pandemic.[2]

Second, we introduce nonlinearities in two ways. Importantly, both v/u and the v/u gap are nonlinear in u. As in several previous USMPF reports, we also explore nonlinear specifications for the measure of slack itself. While the evidence is mixed, nonlinearities provide a modest improvement.[3]

To examine the appropriate path for policy over the coming three years, we use a Phillips curve specification that is estimated over the full historical sample from 1962 to the third quarter of 2022 and is piecewise linear in the v/u gap. As indicated, including the period of high and variable inflation in the estimation period contributes more to the accuracy of the simulations than does the functional form of the Phillips curve. We then use a simple three-equation model of the economy to study policy implications. Specifically, we estimate how high one should expect the policy interest rate to rise to bring inflation back to target over the next three years, and what the cost will be in terms of the unemployment rate. These estimates generally confirm that policy will need to tighten further, with rates going higher than their current level, and that the cost of lowering inflation to the Fed's 2 percent target by 2025 will likely be associated with at least a mild recession.

[2] See Blanchard et al. (2022).

[3] Ball (2022) also employs the v/u measure and other nonlinearities, but does not use the v/u gap, which is our preferred indicator of slack. While our findings are comparable to theirs, they are less definitive. Indeed, none of the modifications we examine allow the Phillips curve to fully explain the evolution of inflation since the start of 2021.

We note that, in coming to these conclusions, we employ a Taylor rule that displays less inertia than is common in the literature (or in the Fed's own FRB/US model). While this is a modeling choice, we view it as having important lessons for policymakers. Had the Fed not jettisoned the gradualism of the past quarter-century in 2022, policy would have been even further behind the curve, with trend inflation and inflation expectations on a higher path than they are today. That is, had policymakers chosen to raise rates in 25-basis-point increments, the cost of the necessary disinflation would be higher.

As Chair Powell acknowledged last year, with the benefit of hindsight it would have been even less costly had the Committee acted preemptively.[4] To be sure, as this and previous USMPF reports confirm, inflation forecasting is very difficult. Indeed, for much of the Great Moderation period, U.S. inflation behaved largely as a constant plus white noise. Nevertheless, a policy strategy based on waiting to see the "whites of the eyes" of inflation can significantly complicate the task of managing a disinflation should the economy be operating significantly above trend. Indeed, from the mid-1980s until the start of the pandemic, U.S. policymakers recognized this fact by embracing a strategy of preemption.

Looking forward, one tempting approach to lowering the cost of disinflation is to raise the inflation target. Importantly, no FOMC participant is advocating such a change. That said, we discuss the case for and against a higher target and conclude that the costs of raising the inflation target—some potentially quite large—almost surely outweigh the benefits.

Improving our knowledge of the inflation process is a recurring theme of the conference papers at the U.S. Monetary Policy Forum, beginning with the inaugural report in 2007 (Cecchetti et al., 2007). More recently, the 2019 USMPF report (Hooper et al., 2019) concluded that "reports of the death of the Phillips curve may be greatly exaggerated." And just last year, Carpenter et al. (2022) stressed the importance of anchoring inflation expectations, particularly after unfavorable supply shocks such as those triggered by the pandemic and the Russian invasion of Ukraine.

The structure of this report is as follows. In section 2 we look at the historical record of sacrifice ratios across four advanced economies. We extend the methodology of Ball (1994) by including more recent observations and a new measure of slack (the v/u gap). As alluded to earlier, there is a wide range in these estimates, and we attempt to identify factors that can help explain this variation. Included in this historical analysis is a deeper dive into the case of the Volcker disinflation. One important lesson from that episode is that the cost of disinflation goes up when the central bank loosens policy prematurely. In section 3 we introduce our three-equation model of the economy. In Section 4 we present various specifications of the Phillips curve, exploring variations of nonlinearities and slack measures to see which model (estimated over which period) can best explain past experience. With these Phillips curve estimates in hand, in Section 5 we use our simple model to generate likely paths of interest rates and the economy over the coming three years. Near term, these simulations anticipate higher policy rates and weaker growth. We then proceed in section 6 to discuss possible benefits and costs of raising the inflation target. Section 7 summarizes our conclusions.

[4] See Ryssdal (2022).

2. Notable disinflations: the historical record

Central bankers now confront a challenge that they have not faced for decades: managing a sizable disinflation. Many observers are concerned that the Fed will get it wrong, either tightening insufficiently to achieve their 2 percent inflation target, or tightening too much and triggering an unnecessarily severe recession. In this section we review the record of post-World War II disinflations and their costs in terms of employment or output in the United States and several other major economies. We conclude with a case study analysis of the most prominent and successful of these past episodes, the U.S. disinflation of the early 1980s.

In our analysis of the sacrifice ratio, we highlight the variation in the relationship between changes in economic slack and inflation over different episodes of disinflation and suggest several factors that may cause that variation. In contrast, in the modeling approach that follows, we constrain the relationship between inflation and slack to be more similar across episodes. As a benefit, modeling allows both for systematic testing of alternative influences on inflation, as well as for simulation and forecasting.

A. Historical record

To start, we identify 17 sizable disinflation episodes in four major countries over a period extending back as far as 1950. Next, we examine the extent to which economic slack increased before and during these disinflation episodes. In doing so, we compute "sacrifice" ratios to gauge the cost of each episode. These ratios measure the increases in unemployment (and, in the United States, in other measures of slack) per percentage point of reduction in inflation. We identify the disinflations that were a primary objective of monetary policy.

Identifying disinflations

We use the algorithm employed by Ball (1994) to identify significant U.S. disinflation episodes since 1950. We start by constructing a measure of *trend* inflation: namely, a nine-quarter centered moving average of quarter-to-quarter annualized price changes. The next step is to identify uninterrupted (peak to trough) declines in this metric.[5]

Figure 2.1 shows the U.S. trend computed using the headline consumer price index (CPI). The blue shading denotes significant disinflations, namely declines that exceed 2 percentage points.[6] The gray-shaded areas are NBER-designated recessions. As the chart makes clear, recessions generally occur early in the disinflation periods. In all, the procedure identifies seven U.S. disinflation episodes in this 70-year period, the final one ending in 2009.[7] Applying the Ball algorithm to the price index of personal

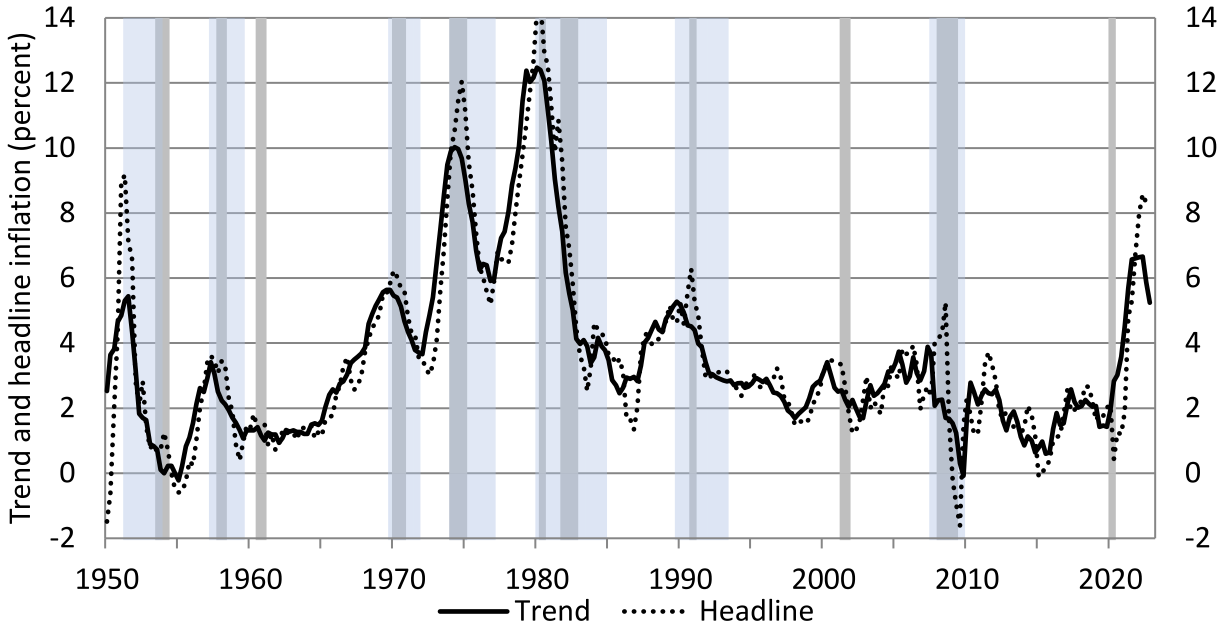
[5] The basic peak/trough dating rules are as follows: a *peak* occurs in the trend when it *exceeds* the levels of both the previous four and subsequent four quarters. Conversely, a *trough* occurs when the trend is *below* the levels of both the previous four and subsequent four quarters. To address the very long U.S. disinflation of the 1990s, we augment this basic rule as follows: for declines in the trend that continue at least four years past the peak in trend unemployment (defined using the basic rule), the trough occurs just prior to the next increase in the trend. Put differently, the trough is a one-quarter low, not a four-quarter low. This augmented rule shortens the 1990s disinflation by four years. It has no effect on other disinflations in the sample.

[6] We include the episode that began in 1969, where the decline in trend headline CPI inflation is 1.94 percentage points.

[7] For two reasons, we do not count as a sizable disinflation the drop in U.S. headline inflation around 2000. First, that decline reflected the reversal of an earlier surge in oil prices that had largely run its course before the recession of 2001. Second, U.S. trend core PCE inflation remained little changed during this period at moderately below 2 percent.

consumption expenditures excluding food and energy (core PCE) also picks out seven significant disinflations since 1950 that are largely coincidental with those shown in Figure 2.1 (for the core PCE trend disinflations, see Appendix chart A.1).

Fig 2.1 United States: Notable disinflation episodes, CPI, quarterly, 1950-2022



Notes: The headline CPI is the year-over-year percentage change of quarterly seasonally adjusted data. The trend line is computed as the 9-quarter centered moving average of seasonally adjusted quarterly changes at annual rates. We extend the trend to 4Q 2022 using quarterly projections through 1Q 2024 from the January 2023 Bloomberg survey of professional forecasters. These consensus forecasts show a decline similar to the median annual projections in the December 2022 FOMC Summary of Economic Projections. Blue shading denotes a sizable disinflation, while the darker gray shading indicates a recession.
Source: Bloomberg, BLS and authors' computations.

Using the same algorithm and historical data back to the 1960s, we also find significant disinflations in three other advanced economies: Canada, Germany, and the United Kingdom. In each case, disinflations occurred in the mid-1970s, early 1980s and early 1990s. In the United Kingdom, there was a further disinflation associated with the global financial crisis that began in 2007.[8]

Table 2.1 provides the start date, duration, and magnitude for each of these disinflations, using both headline CPI and a core price index (core PCE price index for the United States and core CPI for the other economies). In each economy, the early 1980s disinflation was the largest in scale, and of relatively long duration. It was also associated with relatively large increases in the unemployment rate. Those in the mid-1970s also were sizable, as was the early 1950s disinflation in the United States.

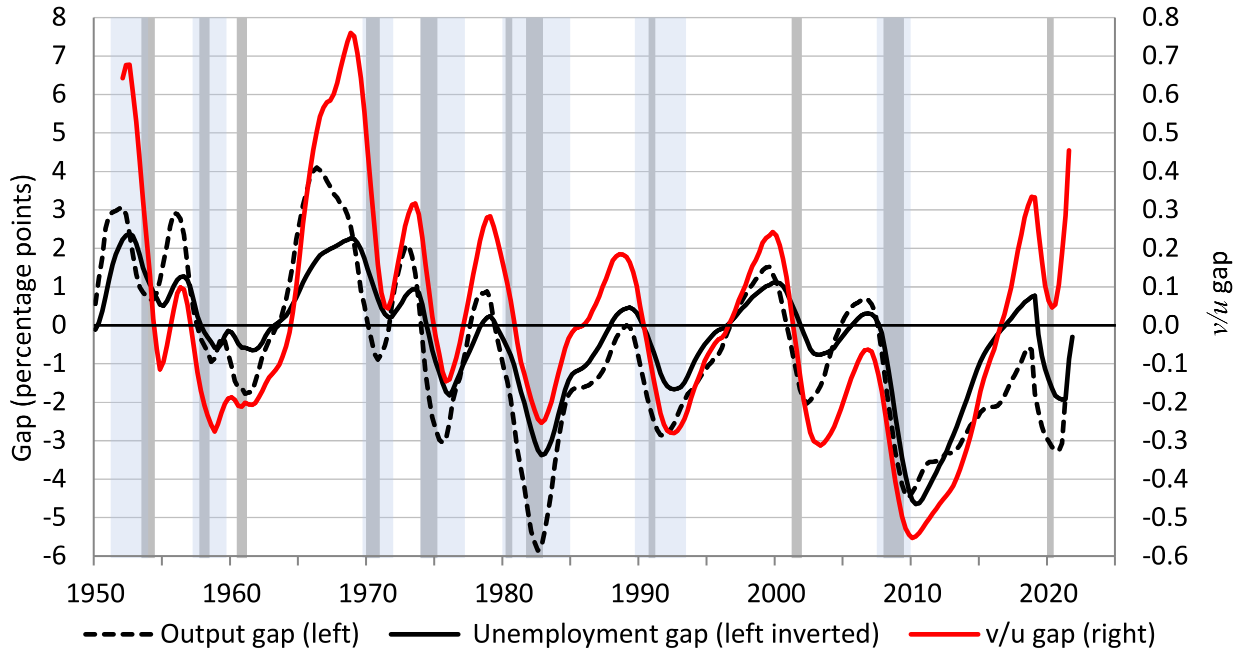
[8] Data availability, combined with our goal of including the high inflation episodes of the 1960s and 1970s, severely limits the number of countries that we consider. While data for Japan are available, we chose not to include them due to the exceptionally modest fluctuations in the unemployment rate. We do observe a cyclical relationship between inflation in Japan and the job offers/seekers ratio that is consistent with our analysis of the *v/u* ratio for the United States.

Table 2.1 Major countries: Notable disinflations, trend measures, 1950 to 2022

	Headline inflation		Core inflation		Unemployment rate	
Start Year	Duration (Quarters)	Amount (p.p)	Duration (Quarters)	Amount (p.p.)	Duration (Quarters	Amount (p.p.)
United States						
1951	11	5.2	15	4.1	11	1.8
1957	10	2.3	20	1.2	11	1.9
1969	9	1.9	8	1.4	13	2.2
1974	13	4.1	6	1.8	11	2.9
1980	16	9.1	17	4.9	16	3.5
1989	15	2.6	24	2.2	13	1.9
2007	10	3.6	13	1.3	15	4.8
Canada						
1974	11	3.5	10	2.7	17	2.6
1981	15	8.1	12	7.1	13	4.5
1990	16	4.9	15	4.8	17	3.7
Germany						
1973	19	4.2	18	3.7	26	3.4
1981	23	6.0	24	4.7	20	4.8
1992	16	3.8	26	5.1	29	5.0
United Kingdom						
1975	14	11.0	9	8.2	15	2.2
1980	26	13.4	26	12.3	28	6.5
1990	14	6.0	18	8.1	14	3.7
2007	28	2.1	20	1.4	19	2.0

Note: All measures in the table are trends computed as the nine-quarter centered moving average of seasonally adjusted data. Inflation measures are based on the CPI, except for the U.S. core measure, which is based on the PCE price index. Start years are shown for the headline CPI and may differ for core. The abbreviation (p.p.) is for percentage points. Inflation is expressed at annual rates in percent.

Figure 2.2 Evolution of U.S. slack metrics, quarterly, 1950-2022



Notes: The trend is calculated as a nine-quarter moving average of each slack measure. Blue shading denotes a sizable disinflation, while the darker gray shading indicates a recession. The vacancy to unemployment gap is the difference of the vacancy to unemployment ratio (v/u) from its noncyclical counterpart (v/u^*).
Sources: BLS, Barnichon (2010) and authors' computations.

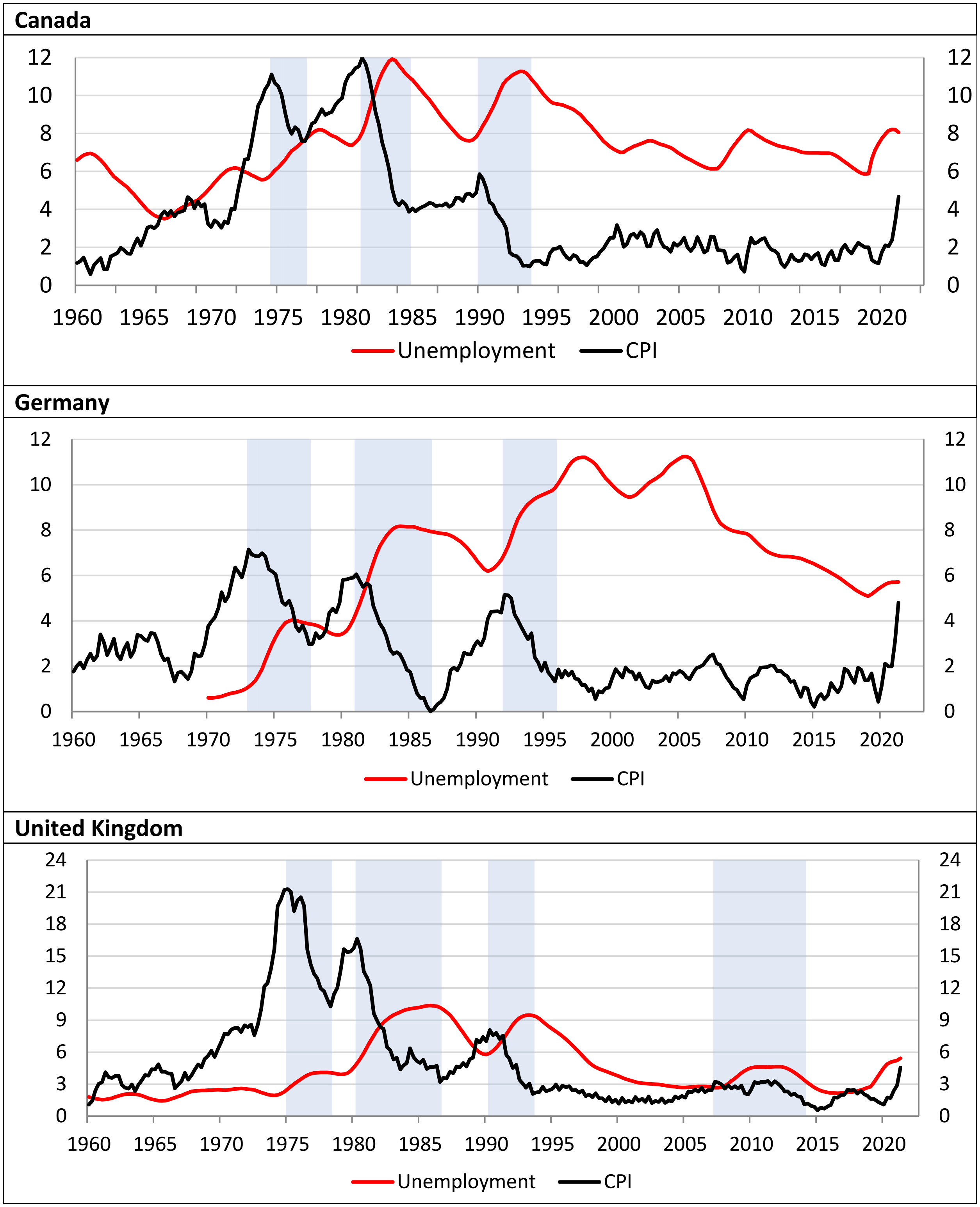
Increases in slack associated with disinflations

Significant increases in economic slack accompanied all these disinflations. For the United States, Figure 2.2 shows the evolving trend of three slack metrics: the output gap between real GDP and the CBO measure of potential GDP; the unemployment gap between the unemployment rate (u) and the CBO estimate of its noncyclical component (u^*); and the vacancy to unemployment gap computed as vacancy to unemployment ratio (v/u) and a measure of its noncyclical counterpart (v/u^*).[9] In each case, ahead of or during disinflation periods, slack intensified sufficiently for the period to be designated as a recession by the NBER Business Cycle Dating Committee.[10] For other countries, Figure 2.3 shows similar patterns. In each case, as we also see in Table 2.1, unemployment rises during disinflations.

[9] The trends in these variables are again computed as nine-quarter centered moving averages. See pages 22-23 in Section 3 for a description of the computation of the noncyclical measure of the vacancy to unemployment ratio (v/u^*).

[10] Unsurprisingly, fluctuations in the output gap (defined as the percentage difference between real GDP and the CBO's measure of potential GDP) exhibit a cyclical pattern consistent with the unemployment gap and the vacancy-to-unemployment ratio.

Figure 2.3 Canada, Germany, and the United Kingdom: Inflation and unemployment trends (percent), quarterly, 1960-2022



Notes: Trends are calculated as nine-quarter centered moving averages. Blue shading denotes a sizable disinflation.

Sources: OECD and authors' calculations.

Monetary policy as driver of disinflations

While the Ball algorithm picks out significant disinflations, it does not tell us whether a particular episode is an intentional result of central bank policy. One way to check this is to examine the record of policy deliberations. Using Federal Reserve records, Romer and Romer (1989) identify episodes when the Fed imposed policy restraint to reduce inflation from undesired levels. These include episodes of policy tightening in the mid-1950s, late 1960s, mid 1970s and late 1970s that roughly correspond to four of the seven U.S. disinflations in Table 2.1.

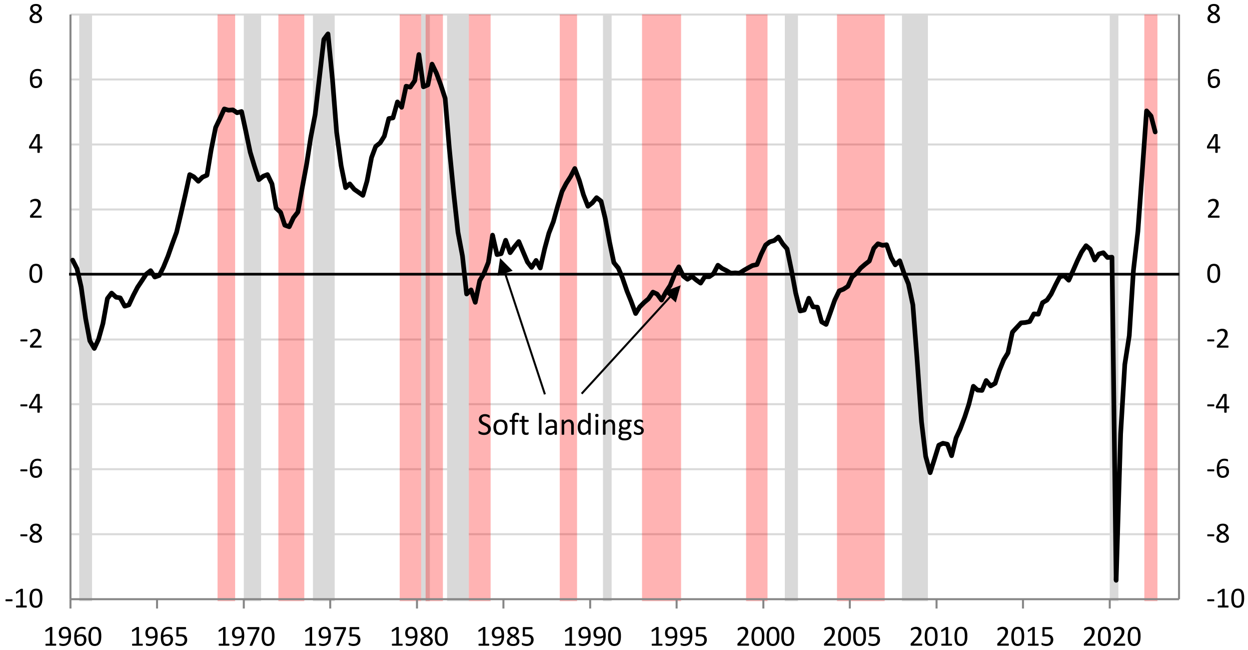
Several observers compare the current episode to the early 1950s when, in the wake of mobilization for the Korean war, shortages of food and consumer durables drove inflation sharply higher, reaching a peak of 9.4 percent. Then, partly because of the imposition of price controls during the war, inflation plunged. The Fed tightened policy only *after* the disinflation had largely run its course. Indeed, Romer and Romer (1989) do not identify this disinflation episode as being a result of intentional Federal Reserve policy restraint. To maintain consistency with their series, we exclude this episode from our analysis of disinflations resulting from monetary policy tightening, reducing the sample shown in Table 2.1 by one. Were we to include this episode, it would have a very low sacrifice ratio. This is consistent with our observations, discussed below, that sacrifice ratios tend to be lower both when starting from a higher inflation rate and when disinflation occurs rapidly.

To confirm a role for monetary policy in the two U.S. disinflation episodes that occurred after the Romer and Romer (1989) analysis, as well as in the disinflations in other countries, we examine the evolution of the real policy interest rate relative to estimates of its equilibrium value (r^*).[11] On this basis, the central banks contributed to each of these disinflations, so we include them in the sample of 16 policy-induced disinflations.

For completeness, we also note two episodes of significant Fed policy tightening—in the mid-1980s and mid-1990s—that did *not* result in recessions and were *not* associated with sizable disinflations. We can see this in Figure 2.4, which plots the sum of the inflation and unemployment gaps (black line) and displays both recessions (gray shading) and periods of Fed tightening (red shading). These “soft landing” episodes did not entail any significant sacrifice because the Fed tightened preemptively at a time when the economy was running very close to desired levels of inflation and unemployment. In those two episodes, in contrast to the situation in 2022, the Fed raised interest rates to *prevent* any significant runup of inflation.

[11] For example, for the U.S. episodes that began in 1989 and 2007, the Federal Reserve raised the *real* federal funds rate one to two percentage points *above* the Holston, Laubach and Williams (2017) estimate of the equilibrium real rate of interest (r^*) prior to the disinflation. For estimating the real interest rate, various measures of inflation expectations (one-year lagged inflation, one-year forward inflation, or contemporaneous 10-year inflation expectations from the FRB/US model) show similar results. For Canada, Germany and the United Kingdom, monetary policymakers raised policy rates aggressively ahead of recessions and disinflations that occurred during the mid-1970s, early 1980s and early 1990s.

Figure 2.4 United States: Sum of inflation and unemployment gaps, quarterly in percentage points, 1960-2022



Note: The inflation gap is the difference between the percent change from a year ago of core PCE prices and the 2-percent target. The unemployment gap is the difference between the unemployment rate and the CBO's noncyclical rate of unemployment. Gray shading denotes recessions. Red shading denotes a policy tightening defined as a period when the ex post real federal funds rate (measured using year-over-year core PCE inflation) rose by at least 3 percentage points or exceeded the Holston-Laubach-Williams (2017) estimate of r^* by at least 1 percentage point. Sources: BEA, CBO, FRBNY, NBER, and authors' calculations.

Sacrifice ratios

We construct sacrifice ratios to compare the relative cost of disinflation across different episodes. The sacrifice ratio we measure is the change in slack associated with a one-percentage-point decline of trend inflation. Here, we compute the sacrifice ratio as the peak-to-trough increase in trend slack divided by the trend disinflation in each episode, where the total increase in slack may occur over a period that differs somewhat from the disinflation period. To measure sacrifice ratios in terms of U.S. core PCE inflation, we extend the BEA measure of core PCE prices back from 1959 to 1950 using the Bolhuis, Cramer and Summers (2022) estimates of core CPI.

Table 2.2 shows estimates of sacrifice ratios using different inflation and slack measures.[12] For the unemployment rate, the unemployment gap and the output gap, the cost of disinflation is measured in

[12] Conventional computations of the sacrifice ratios, such as those in Ball (1994) and Tetlow (2022), use changes in the output gap, or the cumulative shortfall of real GDP from its potential that is associated with the disinflation. In this report, we prefer to use the unemployment gap in part because employment is an explicit element of the Fed's mandate. In addition, estimating the output gap for countries other than the United States present a challenge. That said, for the United States, we consider a range of measures including the unemployment gap and the *v/u* gap defined above, as well as the unemployment rate. Relative to the conventional sacrifice ratio measure, our peak-to-trough approach could overstate the sacrifice because it may include periods at the beginning of downturns when the economy is operating above potential. More likely, however, it understates the sacrifice

percentage declines of output or percentage-point increases of the unemployment rate. For the ratio of vacancies to unemployment, the cost is the reduction in the number of vacancies per unemployed worker. As a result, this latter measure is typically one-half to one order of magnitude smaller than the others. When comparing across countries, data availability leads us to use the headline and core consumer price indexes to measure inflation and the unemployment rate to measure slack.

Table 2.2 Canada, Germany, United Kingdom, and United States: Sacrifice ratios by disinflation episode, 1950-2022

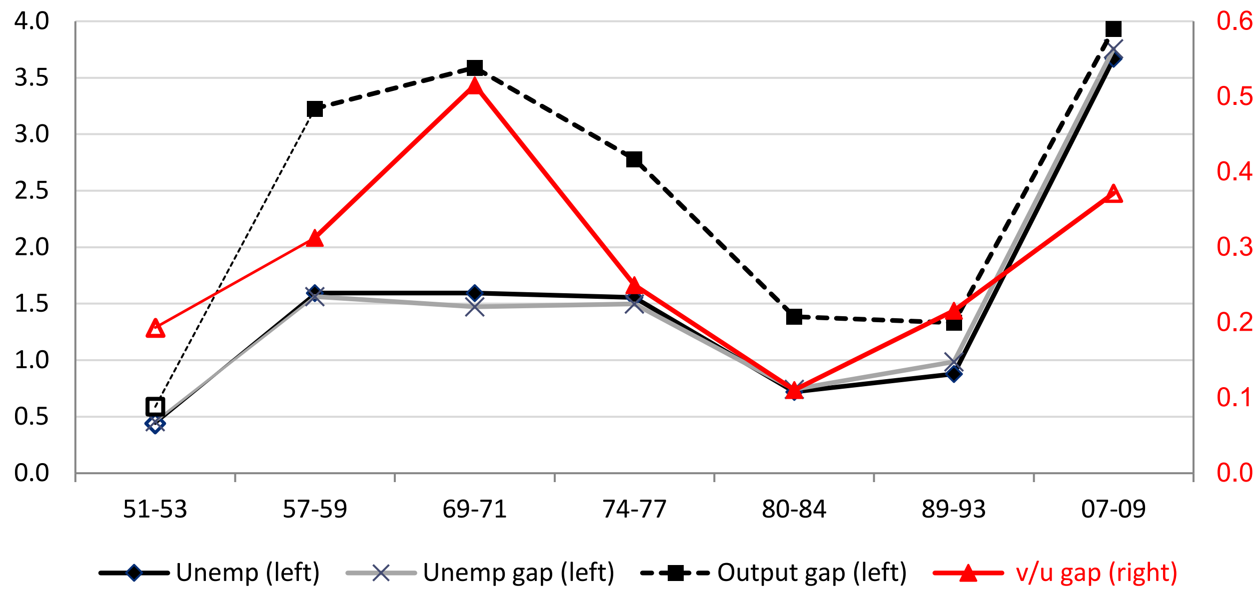
Start	Unemployment		Unemployment gap		Output gap		*v/u* gap	
	Headline	Core	Headline	Core	Headline	Core	Headline	Core
United States								
1951	0.3	0.4	0.4	0.5	0.5	0.6	0.15	0.19
1957	0.8	1.6	0.8	1.6	1.6	3.2	0.16	0.31
1969	1.1	1.6	1.1	1.5	2.6	3.6	0.37	0.52
1974	0.7	1.6	0.7	1.5	1.3	2.8	0.11	0.25
1980	0.4	0.7	0.4	0.7	0.7	1.4	0.06	0.11
1989	0.7	0.9	0.8	1.0	1.1	1.3	0.18	0.22
2007	1.4	3.7	1.4	3.8	1.4	3.9	0.14	0.37
Median (US)	0.7	1.6	0.8	1.5	1.3	2.8	0.15	0.25
Canada								
1974	0.7	1.0						
1981	0.6	0.6						
1990	0.8	0.8						
Germany								
1973	0.8	0.9						
1981	0.8	1.0						
1992	1.3	1.0						
United Kingdom								
1975	0.2	0.3						
1980	0.5	0.5						
1990	0.6	0.5						
2007	0.9	1.5						
Median (ex US)	0.8	0.9						

Notes: Headline is CPI for all countries. Core is PCE for the United States and CPI for other countries. The sacrifice ratio is computed as the change in the trend slack per percentage point change in trend inflation over each episode.
Sources: Barnichon, BLS, BEA, CBO, OECD, and authors' calculations.

because it does not include prolonged periods when the economy is operating below potential during recoveries. In Section 5 we take an alternative approach and compute the sacrifice ratio using model-based simulations of slack and inflation over a fixed period.

Table 2.2 highlights four important patterns. First, each episode of disinflation is accompanied by a significant sacrifice: that is, the numbers are all noticeably greater than zero.[13] Where the reported sacrifice ratio is relatively low, as in the United Kingdom during the 1970s, the magnitude of the sacrifice was nevertheless large, reflecting the large scale of the disinflation. Second, sacrifice ratios moved up in 2007, the final episode in the table. Third, reflecting the greater cyclical sensitivity of food and energy prices relative to core prices, sacrifice ratios are generally higher for core than headline inflation. Finally, sacrifice ratios computed across different measures of slack tend to move broadly together.

Fig.2.5 United States: Sacrifice ratios based on core PCE inflation, 1950-2022



Note: As explained in the text, we do not count the 1951-53 episode as a monetary policy-induced disinflation, but we include the computed sacrifice ratios (denoted by hollow markers) here for completeness.
Sources: Barnichon (2010), BEA, BLS, Bolhuis, Cramer, and Summers (2022), CBO, and authors' calculations.

For core PCE inflation, Figure 2.5 makes the broad co-movement of sacrifice ratios easy to see.[14] All four ratios typically change in the same direction from one episode to the next. In most cases, the latest episode also involves higher ratios than observed from the mid-1970s. Because of the slow change in the noncyclical rate of unemployment, the ratios for unemployment and the unemployment gap are nearly identical. Reflecting Okun's law, these were roughly one-half as large the output gap measures until the 1990s, but the gap narrowed thereafter.

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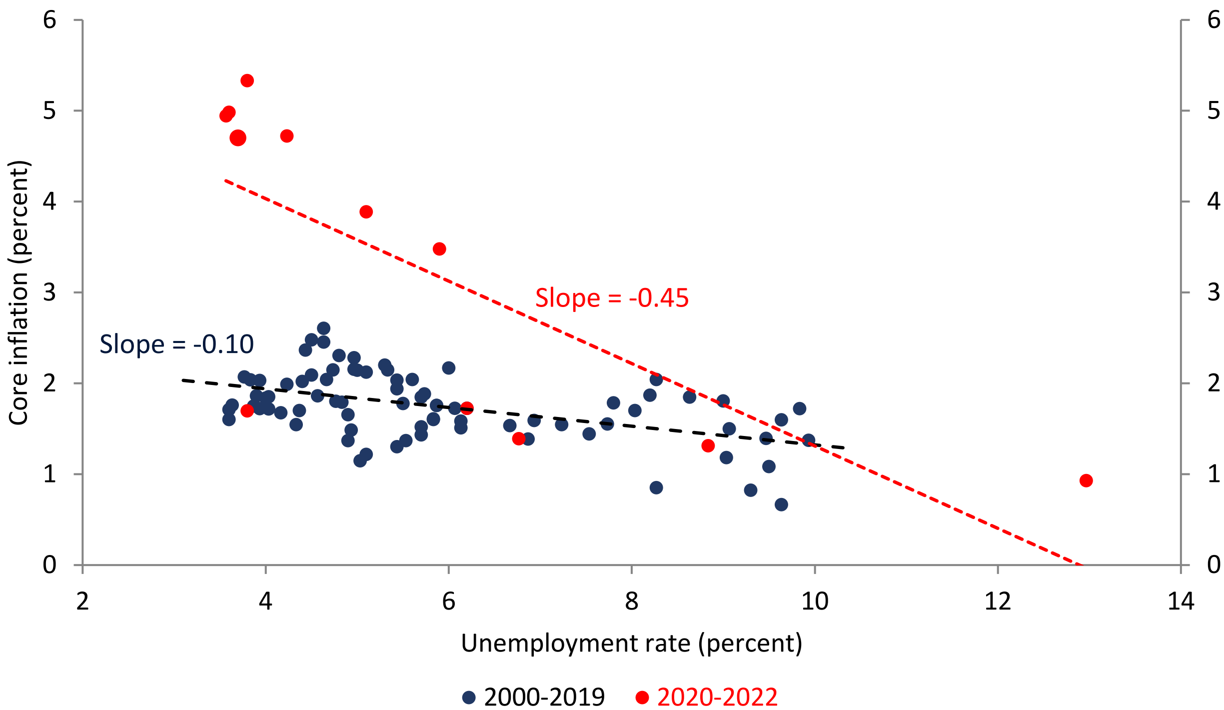
[13] This result is consistent with Ball's (1994) earlier findings for the 1960s, 1970s, and 1980s, across a larger set of countries using quarterly data and output gaps instead of unemployment. Our analysis extends Ball's to the 1990s and 2000s for a subset of the countries he considered. Tetlow (2022) provides a useful survey of published estimates of the U.S. output sacrifice ratio and computes sacrifice ratios with 40 different macro models. Tetlow's estimates are consistently positive and often higher than the ones we report. Indeed, Tetlow's meta-analysis yields a sacrifice ratio estimate that is well in excess of what is implied by the most recent FOMC SEP medians. Chari and Henry (2023) confirm that there is no low-cost way to reduce inflation from moderate levels to low levels based on the experiences of a large number of emerging economies from the mid-1970s to the mid-1990s.
[14] The same co-movement pattern also applies to headline CPI sacrifice ratios.

Factors moving sacrifice ratios

What causes sacrifice ratios to vary over time? Is the recent increase likely to continue? First, theory suggests that sacrifice ratios depend on the credibility of the central bank. Indeed, absent structural impediments (such as long-duration contracts), a perfectly credible central bank would be capable of an "immaculate disinflation" in which inflation declines without any loss of output. Put differently, a credible central bank could lower inflation expectations and eventually lower inflation itself by simply announcing a lower inflation target. The case study of the early 1980s U.S. disinflation at the end of this section addresses the role of central bank credibility in managing disinflation.

Fig. 2.6 United States: Core PCE inflation and the unemployment rate, quarterly, 2000-2022



Notes: The lines are fitted regressions for the relationship between core PCE inflation and the unemployment rate for the two periods. The slope estimates are shown as well.
Sources: BEA, BLS and authors' estimates.

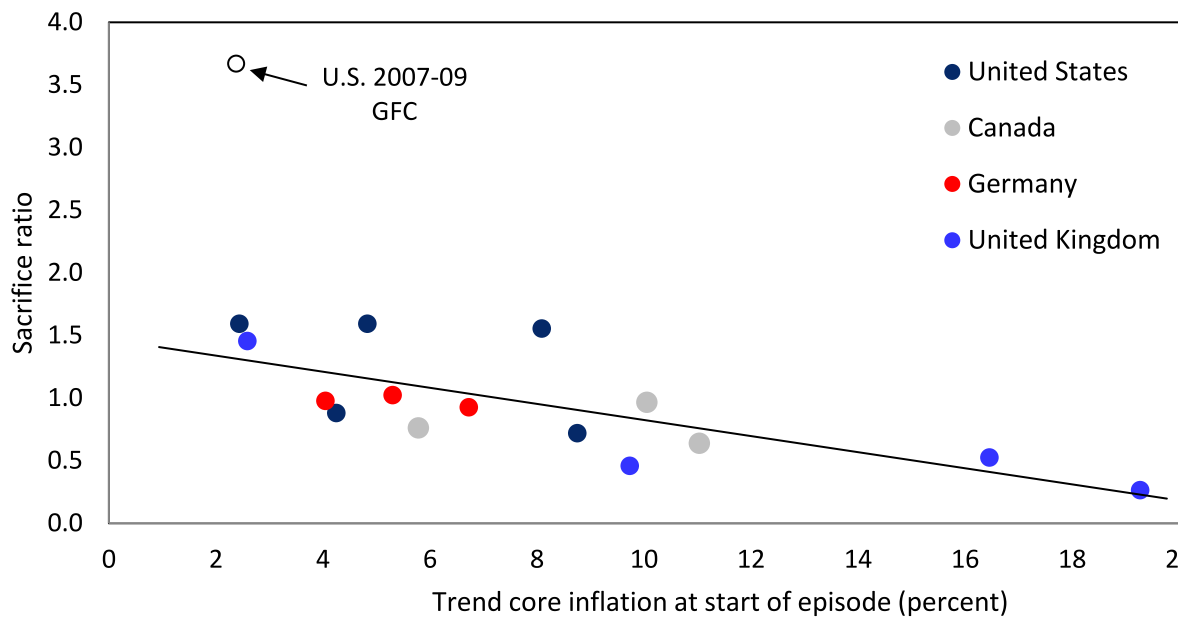
In addition to central bank credibility, the structure of the economy—and especially of the labor market and its dynamics—also affects the costs of disinflation. For example, Ball (1994) finds a significant relationship between labor market flexibility and sacrifice ratios: to the extent that labor market flexibility has increased over time, sacrifice ratios would have diminished, consistent with a steeper Phillips curve.

In fact, the flattening of the Phillips curve since the early 1980s means that each unit of disinflation will be associated with a larger increase in slack.[15] To be sure, post-COVID evidence hints at a renewed steepening of the Phillips curve. For example, Figure 2.6 shows a four-fold increase in the slope of a line

[15] For recent work documenting the flattening of the Phillips curve, see Hooper, Mishkin, and Sufi (2019). Sections 3 and 4 in this report estimate various Phillips curve specifications and discuss their implications for sacrifice ratios.

linking observations of core PCE inflation and the unemployment rate since 2020 (red line) compared to the prior two decades (black line). However, this result is based on only 12 quarterly observations.[16] Moreover, even with the steeper sloped linear Phillips curve, a one-percentage-point decline in core inflation would be associated with a rise of the unemployment rate exceeding two percentage points on impact. A final qualification here is that our preferred specification of the Phillips curve (as discussed in Section 5) is piecewise nonlinear, allowing for different slopes in hot and cold labor markets. The recent steepening is a predominantly hot labor market phenomenon while, as we will see, the slope in cold labor markets remains flat, consistent with a large sacrifice ratio.

Fig 2.7 Canada, Germany, United Kingdom, and United States: Sacrifice ratio and starting level of inflation for each disinflationary episode, 1950-2022



Notes: Each dot corresponds to a disinflationary episode in Table 2.2 and links the sacrifice ratio with the trend measure of core inflation (PCE for the United States and CPI for the others) at the start of the episode. The fitted line excludes the 2007-09 outlier episode in the United States. Sources: OECD and authors' estimates.

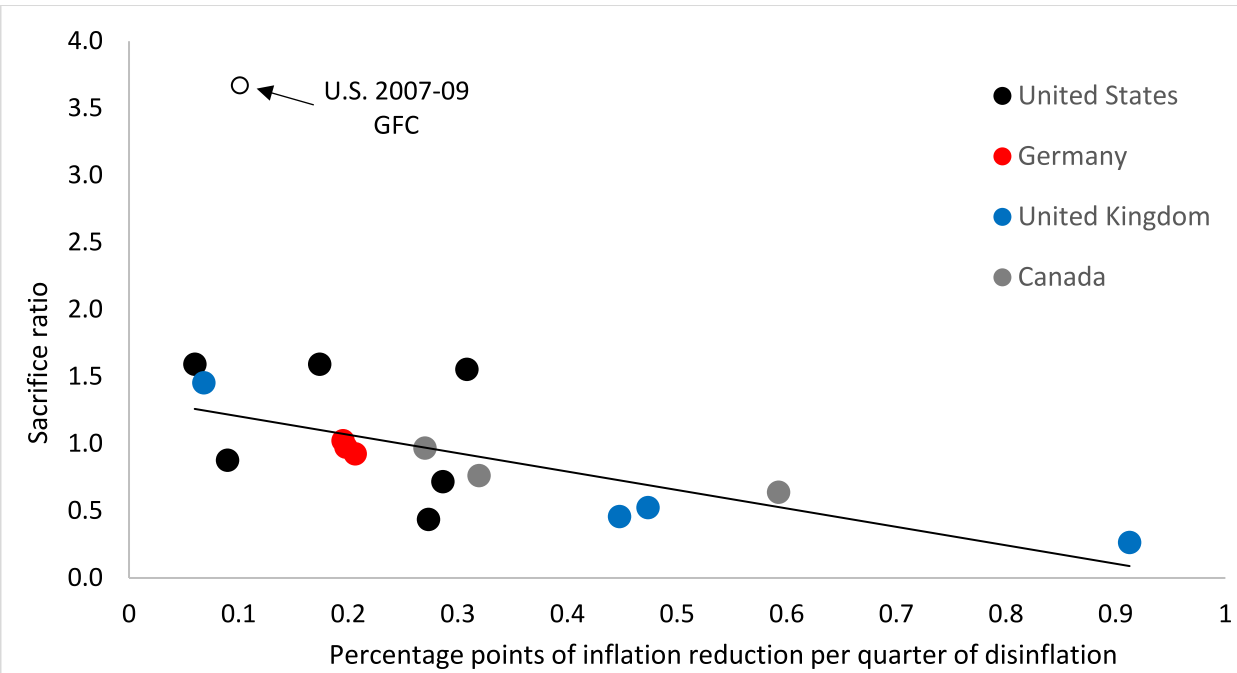
Another factor that appears to influence the cost of disinflation is the starting point for inflation: experience suggests that the sacrifice ratio is *smaller* for disinflations that begin at a *higher* level of inflation.[17] For example, Figure 2.7 maps the relationship between the sacrifice ratio and the level of disinflation at the start of each episode shown in Table 2.2.[18] The pattern suggests that it is easier to reduce inflation from higher starting levels. One reason might be that, at very high levels of inflation, the willingness of a central bank to sacrifice output or employment in order to reduce inflation seems more

[16] See Hobijn et al. (2023) for broader cross-country evidence of a recent steepening of the Phillips curve.
[17] This result is consistent with Ball's (1994) finding for a larger set of countries using quarterly data over the 1960s-80s.
[18] In Figure 2.7, we show the results for core measures of inflation, but they also hold for headline measures. We note that the U.S. episode during the Great Financial Crisis of 2007-09 is a clear outlier. As the housing bubble burst and major intermediaries failed, the tightening of financial conditions in that episode far exceeded the direct impact of policy rate changes. Such financial instability was either lacking or far more muted in other disinflation episodes.

credible. A second possible reason is that high inflation episodes often involve large global supply shocks, as well as demand shocks. This was the case in the 1970s (described below) and in the recent episode. Regardless, the relationship points to a nonlinearity that may become important as disinflation progresses. Namely, the cost of disinflation appears to rise as inflation approaches the central bank's target.

Finally, consistent with the view that monetary policy "gradualism" can be counterproductive, we find that the sacrifice ratio declines with the *speed* of disinflation. For core inflation, Figure 2.8 plots the relationship between sacrifice ratios and disinflation speed—measured as the amount of disinflation per quarter (see columns three and four of Table 2.1). Ball (1994) found much the same result using a different approach and alternative measures of slack across a larger set of countries.[19]

Figure 2.8 Canada, Germany, United Kingdom, and United States: Sacrifice ratio and the speed of disinflation for each disinflationary episode, 1950-2022



Notes: The sacrifice ratios are from Table 2.2. The speed of disinflation is computed as the reduction of inflation per quarter during the disinflation episode (based on the third and fourth columns of Table 2.1). The fitted line excludes the 2007-09 outlier episode in the United States.

Summary: Disinflations had mixed success

Finally, we note that a number of the disinflations in Table 2.2 were unsuccessful in that they did not lead to a sustained period of low and stable inflation. The most obvious examples are the disinflations that ended in the early and mid-1970s. In the United States, for example, the Fed shifted back to a stimulative stance once these recessions started—well before inflation approached a desirable level. In these circumstances, inflation climbed again after the economic downturn.

[19] As in Figure 2.7, the U.S. episode during the Great Financial Crisis of 2007-09 is a clear outlier in Figure 2.8. See footnote 18.

Other disinflation episodes were more fruitful, including the latter 1950s, the early 1980s, and the early 1990s. In three of these four cases, the prevailing level of inflation was relatively modest, and certainly well below current levels. The only successful, monetary-policy induced disinflation that began with a higher level of inflation than the current episode was the Volcker disinflation of the early 1980s, a period we consider in more detail next.

The two key takeaways from our examination of the historical record are: 1) the Fed and other central banks are likely to be hard pressed to achieve their disinflationary goals without a significant sacrifice in economic activity, and 2) the faster the disinflation, the lower the cost.

B. Case study: The 1979-84 Volcker disinflation

To understand better why disinflations are so costly, we examine the Volcker disinflation from 1979 to 1984. By the time Paul Volcker became the Chair of the Federal Reserve in July 1979, previous policy failures had severely undermined the Fed's credibility to control inflation. The Fed was behind the curve: real interest rates were generally negative, with annual headline CPI inflation in the double digits, and core PCE inflation above 5 percent.[20] Expected inflation had also climbed, with the one-year, University of Michigan survey expectation of inflation rising to the 10 percent level and the FRB/US model measure of long-term inflation expectations nearing 7 percent.

There are notable parallels between the economic environment prior to the Volcker disinflation and the one today. In the recent episode, the Federal Reserve also fell behind the curve. In retrospect, its adoption in 2020 of a flawed policy strategy that dropped preemption had weakened its credibility for controlling inflation. It also failed to specify a horizon for restoring average inflation to its target.[21] When inflation began rising in 2021, policymakers focused too much on supply shocks and not enough on demand shocks. As a result, before the Fed began to tighten, real interest rates were negative. Headline CPI inflation again neared double-digit levels and core PCE inflation rose above 5 percent. Expected inflation also rose in the current episode, but not nearly as much as in 1979, with the Michigan one-year survey measure climbing above 5 percent and the Survey of Professional Forecasters' long-term expected inflation edging up slightly from around 2 percent to 2½ percent in the third quarter of 2022.[22] The apparent anchoring of long-term expectations may reflect in part the FOMC's unanticipated shift toward aggressive rate hikes beginning in May 2022.

Returning to the earlier episode, at a surprise press conference on October 6, 1979, Paul Volcker announced that the Fed would allow the federal funds rate to "fluctuate over a wider range," and the federal funds rate climbed to over 17 percent by April 1980. Pressure on the Fed to reverse these rate increases began to build as farmers blockaded the Fed headquarters in Washington with their tractors, homebuilders mailed pieces of lumber to the Chair, and car dealers sent car keys in little coffins. Politicians of both parties strongly urged the Fed to scale back interest rates. We see similar pressures

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[20] See Mishkin (1981)

[21] The adoption of the new framework followed a prolonged period of inflation being "too low" and the Phillips curve being flat. For criticisms of the framework, see Mishkin (2022).

[22] Other measures of long-term inflation expectations, including the 5-year, 5-year forward expected inflation rate and the Cleveland Fed's longer term expected inflation measures, show similar movements.

building currently, and they are likely to broaden and increase dramatically if a recession gets underway.[23]

In May 1980, after a recession began to raise the unemployment rate to over 7 percent, the Fed decided to reverse course and slash the federal funds rate by more than 7 percentage points, even though headline CPI inflation had reached 14.6 percent in April. Inflation expectations also remained stubbornly high: the one-year Michigan survey remained near 10 percent through 1980, while the FRB/US long-term inflation expectations stayed above 7 percent. This sort of premature policy reversal also occurred in the early and mid-1970s, aggravating and extending the period of high inflation.

By 1980, however, the Fed recognized that it had not accomplished its goal of restoring credibility and that its pivot was a mistake.[24] With the recession ending in July 1980, the Fed reversed course. To rebuild credibility, policymakers raised the federal funds rate to nearly 20 percent by the middle of 1981. The economic downturn that started in July 1981 became what was then the most severe recession during the post-World War II era. By the end of 1982, the unemployment rate rose to 10.8 percent. Only after keeping the federal funds rate near 15 percent (and real interest rates above 5 percent) until the middle of 1982 did inflation expectations and the inflation rate start a steady decline to the 3 to 4 percent range in 1983.

The Volcker disinflation episode shows how costly disinflations can be once a central bank has lost credibility for controlling inflation. This experience leads us to draw a critical lesson: should policymakers find themselves in position where inflation is far above target, restoring credibility can require that they abandon monetary policy gradualism and raise policy rates sharply. Furthermore, the Volcker experience also shows that the cost of disinflation is likely to be high when a central bank caves too early to inevitable pressures to stop raising rates.

3. A simple three-equation model

In the next three sections, our goal is to explore how various measures of slack affect trend inflation and policy prospects. Following Carpenter et al. (2022), we do this using a three-equation model, consisting of a modified IS curve (relating labor market conditions and the real interest rate), a modified Taylor rule for setting interest rate policy, and a Phillips Curve (relating a slack variable and inflation). Appended to this is an expectations formation process.

Briefly, the IS curve relates the gap between the unemployment rate (u) and the noncyclical rate of unemployment (u^*) to past values of a measure of slack (such as the unemployment gap itself) and past deviations of the expected real interest rate from its equilibrium rate $[(i_t - \pi_t^e) - r_t^*]$:[25]

[23] As evidence of rising political pressure on the Federal Reserve, see the October 31, 2022 joint letter from members of Congress to the Chair.

[24] One factor that contributed to this mistake was the credit controls implemented by the Carter administration, which caused a temporary, unanticipated sharp cutback in household spending that was not well understood by policymakers.

[25] The specification in Rudebusch and Svensson (1999) is similar. However, Rudebusch and Svensson use the output gap rather than the unemployment gap as the dependent variable and do not explicitly account for inflation expectations in the real interest rate. Separately, we experimented with including in the IS curve the controls for non-oil import price inflation and the ISM manufacturing supplier delivery index that we use in the Phillips curve, but their impact is immaterial.

(1) $$(u_t - u_t^*) = \sum_{k=1}^{2} \phi_k slack_{t-k} + \frac{\kappa}{4}\left[\sum_{m=1}^{4}(i_{t-m} - \pi_{t-m}^e) - r_{t-m}^*\right] + \varepsilon_{IS,t} \ .$$

The modified Taylor rule substitutes the unemployment gap $(u_t - u_t^*)$ for the output gap. As in the Federal Reserve's "balanced approach" rule, we double the usual unit weight on the unemployment gap.[26] In addition, we incorporate interest smoothing, although somewhat less than is typical of *partial* adjustment models of policy setting.[27] The result is as follows:

(2) $$i_t = 0.5 i_{t-1} + (1-0.5)\left[(r_{t-1}^* + \pi_{t-1}^e) + 0.5(\pi_{t-1} - \pi^*) - 2(u_{t-1} - u_{t-1}^*)\right].$$

The third component of our model is a Phillips curve, or aggregate supply equation. Using a standard formulation, inflation depends on lags of both actual and expected inflation, as well as the same measure of slack as we have in the IS curve. Furthermore, to capture the impact of global factors and supply shocks, we include lags in nonoil import price inflation (π^{imp}) and in the manufacturing supplier deliveries index (ISM) from the Institute of Supply Management.[28] The resulting equation is as follows:

(3) $$\pi_t = \alpha + \sum_{j=1}^{4}\beta_j \pi_{t-j} + (1 - \sum_{j=1}^{4}\beta_j)\pi_{t-1}^e + f(slack_{t-1};\gamma) + \sum_{j=1}^{4}\delta_j \pi_{t-1}^{imp} + \sum_{j=1}^{4}\phi_j ISM_{t-1} + \varepsilon_{\pi,t} \cdot$$

Before turning to a detailed discussion of the Phillips curve, we note that using the three-equation model for simulations requires specifying a process for expectations formation. Following Carpenter et al. (2022), equation (4) allows both backward- and forward-looking elements to influence inflation expectations. It imposes some inertia on inflation expectations, which nevertheless converge to the inflation target (π^*) as follows:

(4) $$\pi_t^e = \mu \pi_{t-1}^e + (1-\mu)[\omega \pi_{t-1} + (1-\omega)\pi^*].$$

The parameters of μ and ω in equation (4) determine the pace at which inflation expectations converge to the target. We set μ = 0.96 and ω = 0.30, the values that we estimate over the stable inflation period (1985-2019).[29] By choosing these parameters, we effectively anchor inflation expectations close to the 2 percent level even in the face of large shocks. That is, inflation expectations are extremely sticky, varying

[26] See Federal Reserve *Monetary Policy Report* (June 2022), page 47. Yellen (2017) cites Taylor (1999) in suggesting that the balanced-approach rule could be more effective for economic stabilization than the standard rule that places a unitary weight on the unemployment gap.
[27] For example, the Federal Reserve Bank of Atlanta's Taylor rule utility uses a coefficient of 0.85 on the lagged policy rate (i_{t-1}). While that makes sense for earlier periods when the FOMC moved at a "measured pace," typically in 25-basis-point increments at each meeting, the coefficient of 0.85 implies substantially more persistence than the Committee has exhibited in the 2020-2022 period, amid historically large shifts in both inflation and slack. In this model, the coefficient is 0.5, so there is considerably less policy inertia.
[28] To be sure, our reflection of global factors is far less comprehensive than in Forbes (2019) and in Forbes et al. (2021). Those papers use measures based on non-U.S. inflation over samples beginning in 1990 and 1996, respectively. We leave to future research to extend those methods to include data from the earlier high-inflation episodes of the 1960s and 1970s that are a key focus of this report.
[29] Using a different sample yields a similar estimate of μ (around 0.95), but different estimates of ω. For example, over the pre-pandemic period (1962-2019) with an inflation target of 2 percent, the estimate of ω is 0.93. That is, when we include the pre-1985 period, there is virtually no weight on the 2 percent inflation target.

only very slightly for even relatively large increases in inflation.[30] We note that, since anchoring inflation expectations lowers inflation persistence in the face of shocks, it also *reduces* the economic costs of disinflation that we discuss in section 4. Put differently, this modeling approach is consistent with assuming that the Fed did *not* lose its anti-inflation reputation after the pandemic. It also is largely consistent with the evolution of common financial market measures of expected inflation.

Returning to the Phillips Curve, five key considerations guide our implementation: the measures of inflation, inflation expectations, and slack; the importance of nonlinearities; and the estimation period. We now discuss each of these in turn.

Measuring inflation

While we explored alternative measures of trend inflation (including the median and trimmed mean), in this report we restrict our attention to the traditional trend measured by the price index of personal consumption expenditures excluding food and energy—core PCE inflation. We do this for three reasons. First and foremost, the FOMC states its 2 percent inflation target in terms of PCE inflation, so it is the most natural focus for assessing policy behavior and options. Second, unlike the median or trimmed mean PCE price indexes, core PCE prices are available for the full period. Third, as Bolhuis, Cramer, and Summers (2022) note, 1983 BLS methodological changes that affect the largest component of the consumer price index (CPI)—namely, shelter—do *not* influence the PCE price index.[31]

Measuring inflation expectations

The choice of a measure of inflation expectations is central to the estimation of any Phillips curve. In the 1970s and 1980s, modelers generally assumed adaptive expectations.[32] However, beginning with Roberts (1997), researchers began substituting survey measures of inflation expectations. This choice prompts two further questions: whose expectations, and over what horizon? The answers to these are driven by data availability. Market-based measures based on Treasury inflation-protected securities (TIPS) are only available starting in 1997. And, those measures constructed using models of the nominal term structure begin in 1982.[33] There is a strong case for using firms' inflation expectations.[34] However, the longest history is from the Richmond Fed's Service-Sector Survey of the Fifth Federal Reserve District, which begins in late 1993.

Two measures are available for longer periods: the Philadelphia Fed's Survey of Professional Forecasters (SPF) and the University of Michigan's Survey of Consumers. The SPF quarterly data begins in 1981 and the Michigan survey starts in 1978.[35] Neither captures the full extent of the inflation that began in the mid-1960s. This leads us to adopt the two-part strategy in Carpenter et al. (2022). That is, beginning in

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[30] To see what we mean, consider the case where inflation expectations initially equal inflation, and both are equal to the 2 percent target. Now, assume that inflation jumps to 4 percent and stays there. In that case, our parameter settings imply that inflation expectations will edge up only to 2.15 percent after 8 quarters.

[31] Bolhuis, Cramer, and Summers (2022) argue that adjusting pre-1983 CPI according to the post-1983 methodology would reduce the large 1979-82 core CPI disinflation by more than one-half (from 11 percent to 5 percent) but would not alter the disinflation as measured by the core PCE.

[32] See the discussion in Gordon (2011).

[33] See Haubrich (2009) and the data available at https://www.clevelandfed.org/indicators-and-data/inflation-expectations.

[34] See Coibion, Gorodnichenko, and Kumar (2018).

[35] While the survey began in 1946 as the Livingston survey, consistent quarterly data only starts in 1991.

1975, we employ the series from the Federal Reserve's large-scale macro-econometric model, FRB/US. This measure splices together the SPF (starting in 1981) with a series generated from the model of Kozicki and Tinsley (2001). Their model effectively assumes adaptive expectations of boundedly-rational agents with a shifting intercept in an autoregressive model of inflation. Then, prior to 1975, we use a 40-quarter moving average of quarterly headline PCE inflation at an annual rate. [36] We note that the relationship between our long-term expectations measure and the short-term Livingston survey is relatively stable over period from 1962 to 1981, when the SPF begins.

Measuring slack

Turning to the appropriate measure of slack, recent work focuses on alternatives to the unemployment gap and the output gap. One reason is that we know neither u^*—the noncyclical component of unemployment—nor the level of potential output (y^*). For example, Orphanides (2002) argues that underestimates of u^* contributed to the large inflation policy errors of the 1970s. A second motivation today is that Phillips curve models using the unemployment gap severely underestimated the scale and persistence of inflation in 2021 and 2022. As the upper panel of Figure 3.1 shows, the unemployment gap in 2022 was no more negative (inflationary) than it had been in 2019, when core PCE inflation was below 2 percent.

The weakness of unemployment gap models led Ball et al. (2022) to consider the ratio of vacancies to unemployment (v/u). This now-popular ratio plays a central role as an indicator of labor market tightness in modern theories of labor market search and matching.[37] These models make the empirically supported assumption that the number of job matches is an increasing function of both vacancies and the number of unemployed workers. The (v/u) ratio is a convenient measure of labor market tightness in the sense that real wages should covary positively with this variable. The intuition is that when (v/u) increases employers seek workers more frequently than workers seek jobs. The increase in their bargaining power allows workers to capture more of the surplus of a successful match.

To use (v/u) as a measure of slack, we need a sufficiently long time series for vacancies. The BLS Job Openings and Labor Turnover Survey (JOLTS) began publishing vacancy data monthly in December 2000. To extend this series to 1951, Barnichon (2010) uses help-wanted information.[38] Combining these two sources results in the black line in the bottom panel of Figure 3.1. As the chart highlights, and as Ball et al. (2022) emphasize, the unprecedented rise of v/u in 2021-22 virtually coincides with the post-COVID increase of trend inflation.[39] However, there is evidence that the relationship between v/u and inflation changes significantly over time. For example, v/u reached its pre-COVID peak of 1.52 in 1969, when core PCE inflation was 4.7 percent. In contrast, in 1980 core PCE inflation was nearly twice as high (9.2 percent), while the v/u ratio (0.73) was only one-half of the 1969 peak.[40]

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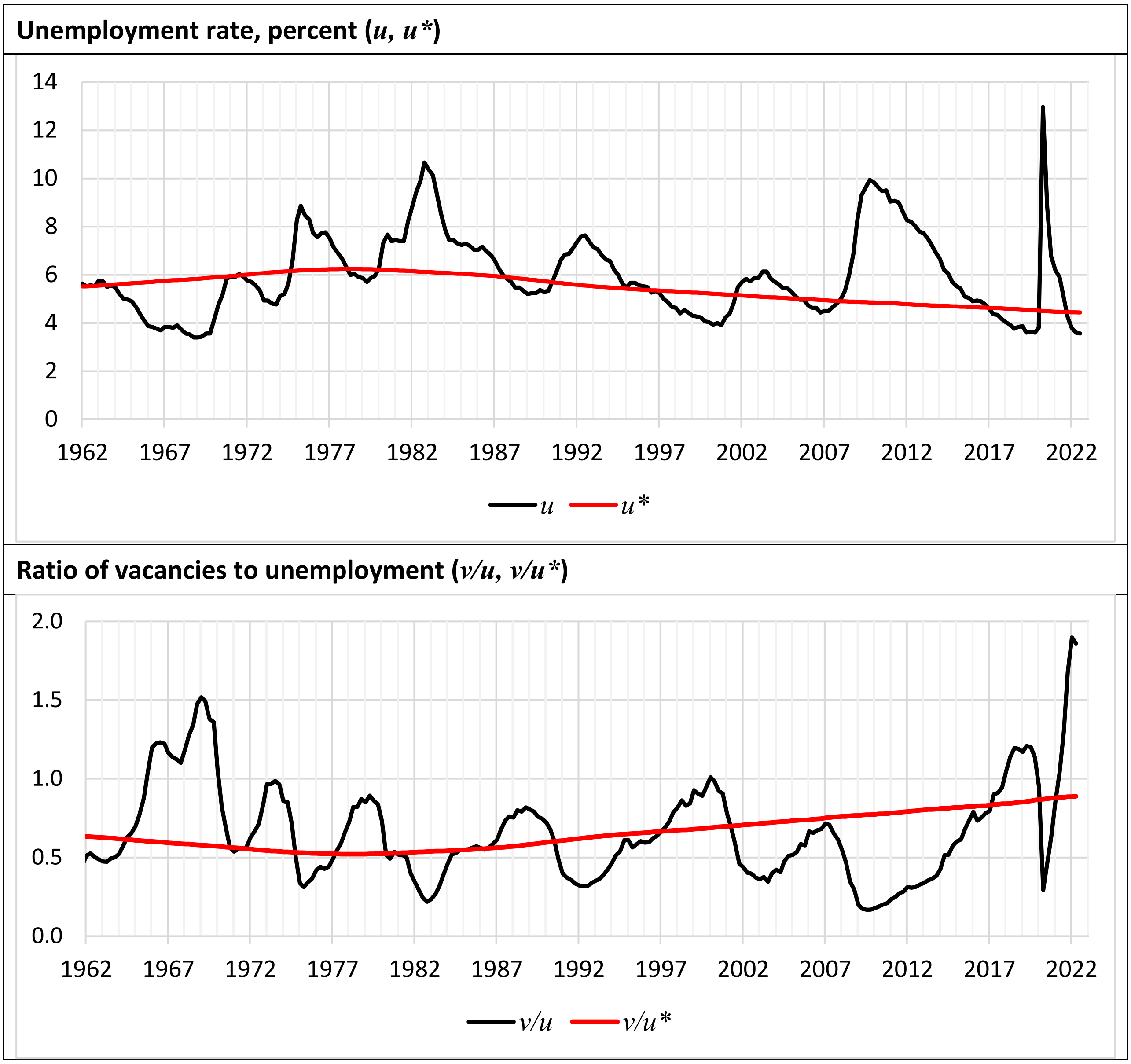
[36] This procedure yields results that are very similar to those from the exponentially weighted moving average of Kozicki and Tinsley (2001).
[37] See the description in Pissarides (2000).
[38] Unfortunately, we do not have a long history for other useful measures of labor market slack, like quits.
[39] Notably, the recent episode is still sufficiently brief that when we smooth the data for v/u or the v/u gap (as in Figure 2.2 red line), the trend still falls short of the peak in the late-1960s.
[40] Şahin (2022) criticizes the use of *v/u* as a slack metric for inflation prediction by noting their changing relationship over the full period since the 1960s.

Figure 3.1: Measures of slack, 1962-2022



Note: u^* is measured as the noncyclical rate of unemployment and v/u^* is measured using the fitted values of equation (5) in the text.
Source: BLS, Barnichon, CBO, and authors' calculations.

While we consider v/u a useful slack indicator, for consistent analysis over long periods it is important to take account of the evolution of its noncyclical trend, v/u^*. This approach is analogous to using the unemployment gap, which adjusts the unemployment rate (u) for the evolution of its noncyclical trend (u^*). Estimating v/u^* requires that we estimate v^*, the noncyclical rate of vacancies. We do this using the following procedure. First, we estimate a log-linear relationship between the vacancy rate and the unemployment rate:

(5) $\ln(v) = a + b\ln(u) + \varepsilon$.

This is a Beveridge curve.[41] We then estimate the noncyclical rate of vacancies as the fitted values from (5) using the noncyclical rate of unemployment. That is:

$$(6) \quad \ln(v^*) = \hat{a} + \hat{b}\ln(u^*) \ .$$

From this, we can compute a measure of the noncyclical ratio (v/u^*), shown as the red line in the bottom panel of Figure 3.1. We then define the vacancy to unemployment gap as $(v/u - v/u^*)$. This gap formulation takes account of outward shifts in the Beveridge curve, but not of changes in its curvature.[42]

Table 3.1: Summary statistics for measures of slack, 1962-2019, quarterly

	(u-u^*) percentage points		($v/u - v/u^*$)	
	Pre-pandemic period (1962-2019)	Stable inflation period (1985-2019)	Pre-pandemic period (1962-2019)	Stable inflation period (1985-2019)
St Dev	1.61	1.53	0.31	0.26
Hot	-1.20	-0.81	0.35	0.20
Cold	2.79	1.53	-0.37	-0.48
Mean	0.47	0.72	-0.01	-0.11
Median	0.11	0.31	-0.03	-0.09

Note: For the unemployment gap, hot is the 10th percentile and cold is the 90th percentile. For the vacancy to unemployment ratio gap, hot is the 90th percentile and cold is the 10th percentile.
Source: BLS, Barnichon, CBO, and authors' calculation.

Table 3.1 reports summary statistics for both the unemployment gap and the v/u gap for two periods: the Great Moderation (stable inflation) period from 1985 to 2019 and the full pre-COVID interval from 1962-2019. We define the "Hot" portion of the distribution as the bottom decile of the unemployment gap and the top decile of the v/u gap. The converse applies to the "Cold" portion of the distribution. The relative stability of the Great Moderation is reflected in the lower standard deviations of both measures, as well as the narrower gaps between the top and bottom deciles.

In what follows, we examine both the unemployment gap and the vacancy to unemployment gap.

Nonlinearities

The third issue in specifying the Phillips curve is whether to introduce nonlinearities, and if so, how. As the Great Moderation progressed, estimates of the coefficient on slack in linear versions of the Phillips curve such as Blanchard (2016) declined toward zero. However, the apparent "flattening" of the curve may simply reflect the success of the Federal Reserve in stabilizing inflation. Indeed, over the period of the Great Moderation, inflation was roughly a constant plus white noise, which is what we would expect

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[41] Over the full historical period, 1962-2022, we estimate the parameters of (5) as $a = 2.20$ and $b = -0.57$. So, in levels, the relationship is a hyperbola where $v = 2.2u^{-0.57}$. This ignores the structural shifts in the Beveridge curve that occurred during these 60 years. For the simulations in section 5 of this report, we estimate the Beveridge curve over the 2020-2022 sample, resulting in parameters $a = 2.36$ and $b = -0.40$ so that $v = 2.36u^{-0.4}$.

[42] Blanchard, Domash and Summers (2022) argue that, in the aftermath of the COVID pandemic, a combination of deterioration in the job matching technology and an increase in sectoral reallocation led to a large outward shift of the Beveridge curve that is unlikely to reverse quickly. The implication is that unemployment will have to rise significantly as the economy cools; put differently, u^* has risen substantially. In contrast to Blanchard, Domash and Summers (2022), Figura and Waller (2022) treat the post-COVID rightward shift in the Beveridge curve as transitory, so that a decline in the vacancy rate need not lead to a rise in the unemployment rate.

if policymakers reacted to shocks optimally. In that case, there will be no correlation between inflation and any measure of slack, so the estimated coefficient in a Phillips curve regression will be biased towards zero. Moreover, some observers, including Hooper, Mishkin and Sufi (2020), suggest that a steeper Phillips curve would reemerge if policymakers were to abandon preemption or the labor market were to become sufficiently tight. More recently, Ball et al. (2022) argue that nonlinearity—in the form of a cubic function—is key to explaining the usefulness of v/u as a slack measure. Finally, recall from the discussion in Section 2 that disinflations which begin with higher inflation rates are associated with lower sacrifice ratios.

In our work, we investigate three forms of nonlinearity. First, we note that the v/u gap itself is nonlinear in unemployment. So the simplest linear specification,

(6) $f(slack;\boldsymbol{\gamma}) = \gamma_0 slack_{t-1}$,

intrinsically includes some nonlinearity when v/u is the slack metric.

Second, we use two explicitly nonlinear specifications. Following Ball et al. (2022), we specify slack as a cubic function:

(7) $f(slack;\boldsymbol{\gamma}) = \gamma_1 slack_{t-1} + \gamma_2 slack_{t-1}^2 + \gamma_3 slack_{t-1}^3$.

Third, we use a piecewise linear specification that allows for an asymmetric response of inflation to hot and cold slack measures. We write this as:

(8) $f(slack;\boldsymbol{\gamma}) = \gamma_c(slack_{t-1} > 0) + \gamma_h(slack_{t-1} < 0)$,

and refer to this as the "Hot/Cold" specification.[43] This functional form is broadly consistent with our empirical finding that the sacrifice ratio associated with a disinflation episode depends on the starting level of inflation (see Figure 2.7).

Estimation Period

Finally, there is the issue of the sample period. The availability of estimates of the equilibrium real interest rate in the IS curve (r^*) mean that we start in 1962. Furthermore, we choose to use a quarterly frequency. Most importantly, however, we estimate the various models over sample periods that either include the 1960s and 1970s or do not. And, in both cases, we end in 2019. So, we look at two samples: 1962 to 2019 and 1985 to 2019. Later, in simulations, we will show results based on data through the third quarter of 2022. We note that in predicting the recent inflation surge, it turns out that the estimation period is of greater consequence than the specification of the Phillips curve.

4. Phillips curve estimates and inflation predictions

In this section, we first present estimates of the various Phillips curve specifications, and then see whether any of these can predict the out-of-sample pattern for inflation. That is, when we consider the different measures of slack and various nonlinear functional forms, are we able to match the dramatic increase in inflation that began in mid-2021?

[43] The piecewise linear specification also is consistent with the use of a slack dummy in Forbes et al. (2021). Those authors find that the inclusion of a slack dummy improves their Phillips curve estimate.

A. Estimates

Starting with the results, we estimate 12 variations of the Phillips curve: 2 measures of slack (u-u^* and v/u -v/u^*), three functional forms for the slack variable (linear, cubic, and Hot/Cold), and 2 sample period (1962 to 2019 and 1985 to 2019). All data is quarterly and seasonally adjusted. We measure inflation as quarterly changes at annual rates.

Tables 4.1 reports the results for the long sample, while Table 4.2 contains those for the shorter sample. For the cubic specification we report the estimated value of the impact of a marginal change in slack evaluated at either the hot or cold levels of slack (from Table 3.1). Labeled "Slope (Hot)" and "Slope (Cold)" in Table 4.1, these can be compared to the "Hot (λ_1)" and "Cold (λ_2)" coefficients shown in the piecewise linear ("Hot/Cold") estimates.

Looking at the results, starting with the longer sample in Table 4.1, we note the following. First, focusing on the p-values of the estimates, the v/u gap measure looks superior. Second, slope estimates for the cubic are very similar to the Hot/Cold specification.[44] Third, the estimated sum of the coefficients on lagged inflation is between 0.82 and 0.89, suggesting that shocks to inflation are quite persistent.

Finally, in our preferred v/u gap Hot/Cold specification, we see that hot labor markets have a large and precisely estimated positive impact on inflation (coefficient of 0.680), while cold labor markets have virtually no impact at all (coefficient of -0.026). This asymmetry is inconsistent with the belief that monetary policy can reduce inflation by pushing v/u below v/u^*. Our estimates suggest policymakers can reduce upward pressure on inflation by moving v/u down to v/u^*, but further reductions of v/u have little impact on inflation. From this we infer that it is risky for policymakers to allow the labor market to overheat. Indeed, if inflation expectations are not anchored, the cost of disinflation could be very high.

Turning to the results in Table 4.2, we see that these estimates verify previous findings that aggregate Phillips curves estimated over the stable inflation period appear very flat.[45] This is true regardless of the measure of slack or of the functional forms. Second, the sum of coefficients on lagged inflation are now about 0.6, suggesting shocks die out quickly.[46] Third, these equations fit the data relatively poorly. While the R^2 for the regressions in Table 4.1 are all about 0.72, for the stable inflation period they are 0.32.[47]

[44] We note that the estimated cubic equation is well-behaved over the observed range of the slack variable. For example, in the v/u gap model (column 5), the estimated impact of a change in the v/u gap is positive for values in excess of -0.6, which is the minimum in the sample. This also applies to the estimated u model (column 3).

[45] See, for example, Cecchetti et al. (2019).

[46] When the sum of the coefficients on inflation is 0.85, the half-life of a shock is 4 quarters. For a value of 0.6, it is just over one quarter.

[47] We also examined the 1962-1984 period. Those estimates are very similar to the ones we obtain when using the pre-pandemic sample reported in Table 4.1. For example, the estimated sum of the coefficients on lagged inflation is around 0.9 and the coefficients on the v/u gap Hot/Cold model are 0.7 (hot) and 0.1 (cold).

Table 4.1 Phillips Curve: Alternative specifications, core PCE inflation, pre-pandemic sample, quarterly

		Measure of slack					
		$(u\text{-}u^*)$			$(v/u - v/u^*)$		
		Linear	Cubic	Hot/Cold	Linear	Cubic	Hot/Cold
		(1)	(2)	(3)	(4)	(5)	(6)
Linear	Slack (γ_0)	-0.046 (0.21)			0.325 (0.09)		
Cubic	Slack (γ_1)		-0.088 (0.15)			0.799 (0.01)	
	Slack^2 (γ_2)		0.024 (0.42)			0.941 (0.07)	
	Slack^3 (γ_3)		-0.002 (0.80)			-1.715 (0.03)	
	Slope (Hot)		-0.154 (0.15)			0.751 (0.03)	
	Slope (Cold)		0.006 (0.91)			-0.550 (0.24)	
Piecewise linear	Hot (λ_1)			-0.164 (0.10)			0.680 (0.05)
	Cold (λ_2)			-0.014 (0.76)			-0.026 (0.93)
Lagged inflation	$\sum_{j=1}^{4} \beta_j \pi_{t-j}^{core}$	0.891 (0.00)	0.870 (0.00)	0.838 (0.00)	0.868 (0.00)	0.881 (0.00)	0.852 (0.00)
Controls	$\sum_{j=1}^{4} \delta_j \pi_{t-j}^{imp}$	0.009 (0.55)	0.013 (0.40)	0.014 (0.39)	0.012 (0.45)	0.011 (0.48)	0.014 (0.37)
	$\sum_{j=1}^{4} \phi_j ISM_{t-j}$	0.038 (0.00)	0.034 (0.02)	0.033 (0.02)	0.035 (0.01)	0.030 (0.04)	0.031 (0.03)
	R^2	0.719	0.721	0.721	0.721	0.726	0.723

Note: Values in parentheses are p-values, $p<0.01$, $p<0.05$, $p<0.10$, computed using heteroskedasticity-consistent standard errors.

Table 4.2 Phillips Curve: Alternative specifications, core PCE inflation, stable inflation sample, quarterly

		Measure of slack					
		$(u\text{-}u^*)$			$(v/u - v/u^*)$		
		Linear	Cubic	Hot/Cold	Linear	Cubic	Hot/Cold
		(1)	(2)	(3)	(4)	(5)	(6)
Linear	Slack (γ_0)	-0.012 (0.70)			-0.009 (0.96)		
Cubic	Slack (γ_1)		-0.101 (0.12)			0.189 (0.62)	
	Slack^2 (γ_2)		0.056 (0.27)			-0.709 (0.60)	
	Slack^3 (γ_3)		-0.007 (0.48)			-2.029 (0.51)	
	Slope (Hot)		-0.209 (0.14)			-0.437 (0.61)	
	Slope (Cold)		-0.046 (0.54)			-0.544 (0.57)	
Piecewise linear	Hot (λ_1)			-0.108 (0.41)			0.312 (0.60)
	Cold (λ_2)			0.003 (0.94)			-0.136 (0.67)
Lagged inflation	$\sum_{j=1}^{4} \beta_j \pi_{t-j}^{core}$	0.602 (0.00)	0.592 (0.00)	0.600 (0.00)	0.611 (0.00)	0.643 (0.00)	0.610 (0.00)
Controls	$\sum_{j=1}^{4} \delta_j \pi_{t-j}^{imp}$	-0.022 (0.27)	-0.019 (0.31)	-0.020 (0.31)	-0.022 (0.25)	-0.022 (0.26)	-0.022 (0.26)
	$\sum_{j=1}^{4} \phi_j ISM_{t-j}$	0.034 (0.03)	0.031 (0.07)	0.033 (0.04)	0.035 (0.03)	0.036 (0.04)	0.033 (0.06)
	R^2	0.319	0.329	0.321	0.318	0.321	0.320

Note: Values in parentheses are p-values, $p<0.01$, $p<0.05$, $p<0.10$, computed using heteroskedasticity-consistent standard errors.

There are several reasons that our results differ from those in Ball et al. (2022). First, and most importantly, we use a longer sample period. Our estimates use data starting from 1962, while their sample begins in 1985. That is, we include the period of high and volatile inflation that runs from the late 1960s to the early 1980s. Second, we take account of the large outward shifts in the Beveridge curve by computing the *v/u* gap.[48] Third, we use the FOMC's preferred inflation measure—the PCE price index excluding food and energy—rather than the median CPI. Finally, we measure global factors and supply disturbances using the combination of relative non-oil import prices and the ISM manufacturing supplier deliveries index. By contrast, Ball and coauthors proxy supply shocks as the difference between headline and median CPI.

We draw the following key lesson from these results: both the flat estimated Phillips Curve and the lower persistence of inflation shocks (regardless of the source) in the Great Moderation period are consistent with the importance of central bank credibility and preemption. Put differently, these features of the Great Moderation reflect at least in part the Federal Reserve's reputational gains from the Volcker disinflation episode previously discussed. Our model estimates underscore the value of preemption. Since a cold labor market does not drive inflation lower, the costs of disinflation can be high. As a result, preemption is essential to prevent a hot labor market from raising inflation.

B. Inflation predictions

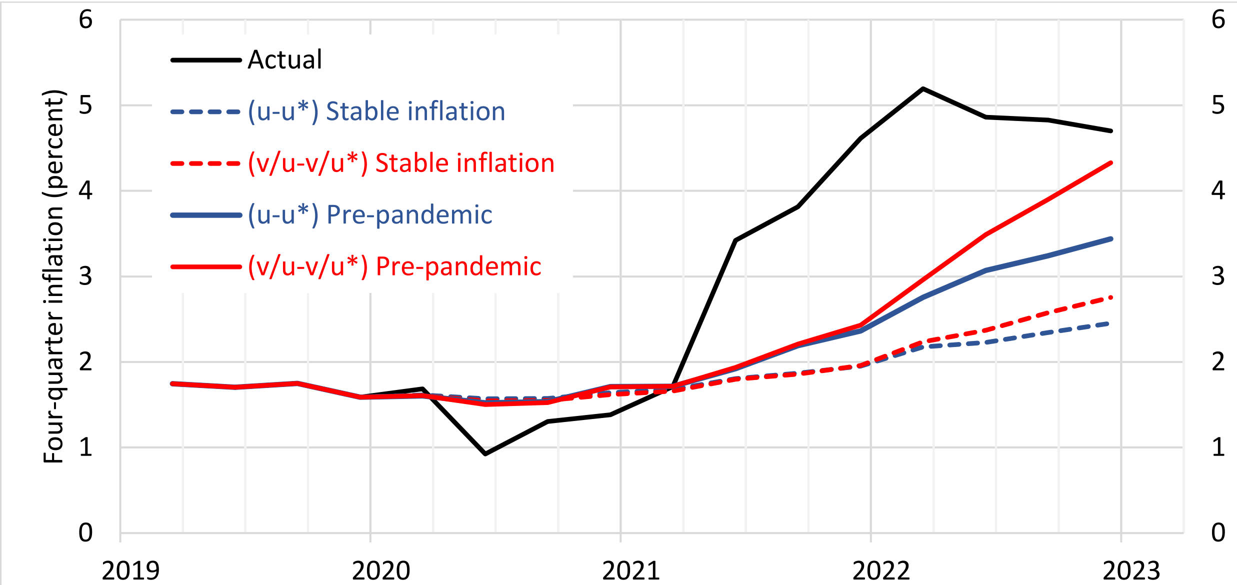
If we had been using these models in early 2020 and had we known the future values of the controls and slack variables, would we have predicted the burst of inflation? To answer this question, using estimates both from the stable inflation period and from the pre-pandemic period, we run the models forward dynamically and generate inflation predictions for the period from the start of 2020 to the end of 2022. Figure 4.1 shows the results of this exercise for the Hot/Cold models using each of the slack measures—u gap ($u - u^*$) and v/u gap ($v/u - v/u^*$). In each case, the solid lines depict the path for the pre-pandemic period and the dashed lines for the stable inflation period. Realized inflation is the solid, black line.

What stands out in Figure 4.1 is that the sample period matters more than the measure of slack for prediction accuracy. To see this, consider the deviations from actual inflation in the fourth quarter of 2022. On average, the solid lines (based on the pre-pandemic period) are on average 0.9 percentage points below actual inflation, while the dashed lines (based on the stable inflation period) fall short by 2.1 percentage points. By contrast, the u gap model (in blue) is on average 1.8 percentage points below the actual, while the v/u gap model is 1.2 percentage points too low. That is, the sample period improves the accuracy of the prediction by about twice as much as the slack measure.

Given that we construct the predictions from estimates based on samples that include long periods of preemptive policy, the recent underprediction is unsurprising given the 2020 shift away from preemption. Precisely because of this change in policy strategy, the exercise highlights the benefits of using the longer data sample. Table 4.3 provides the root-mean-square errors (RMSEs) for the inflation predictions shown in Figure 4.1. The errors are uniformly smaller for estimates based on the pre-pandemic period. The reason is almost surely that inflation exhibited little variation over the stable inflation period; as a result, any out-of-sample inflation predictions remain close to 2 percent regardless of labor market slack metrics or of supply shocks. As for the outperformance of the *v/u* gap model (relative to the *u* gap model), we note that in 2022 the former measure of slack surpassed its sample peak (1969), while the unemployment gap was at its pre-pandemic level.

[48] The combination of the longer sample and the use of the v/u gap is important as it means we include the mid-1960s period when, by this measure, the labor was nearly as tight as it is now.

Figure 4.1 Inflation predictions: Hot/Cold models, out-of-sample, 2020 – 2022



Source: Authors' calculations based on Phillips curve models estimated over the pre-pandemic period (1962-2019) and the stable inflation period (1985-2019) reported in Tables 4.1 and 4.2.

Our interpretation of these results is that the FOMC's strategy of preemption in the stable inflation period made both inflation and inflation expectations stable. In that environment, shocks dissipated rapidly. The improved performance of all our Phillips curve models estimated over the pre-pandemic period suggests that the recent strategic shift away from preemption *restored the pre-1985 pattern of greater persistence of movements in both inflation and (to a much lesser extent) inflation expectations*. This is particularly important because, based on our estimates, slack plays such a modest role in determining inflation in cold labor markets.

Table 4.3 RMSE for inflation: Various models, percent, 2020 – 2022

Phillips Curve Specification	Sample for Estimation: Pre-pandemic period (1962-2019)	Sample for Estimation: Stable inflation period (1985-2019)
	(u-u)*	
Linear	1.83	2.30
Cubic	1.83	2.51
Hot/Cold	1.84	2.30
	(v/u – v/u)*	
Linear	1.67	2.28
Cubic	1.74	3.49
Hot/Cold	1.67	2.19

Source: Authors' calculations based on Phillips curve models estimated over 1962 to 2019 reported in Table 4.1.

5. Three-equation model simulations

We now return to the three-equation model introduced in Section 3. That is, we start with the Phillips curve estimates based on the full historical sample (1962–3Q 2022), focusing on our preferred v/u gap Hot/Cold specification. The IS curve (equation 1 on page 20) relates the unemployment gap to the measure of slack (v/u gap) and the gap between the current and equilibrium real interest rate.[49] Finally, we use a modified, balanced-approach Taylor rule with a partial adjustment parameter set to 0.5 (equation 2 on page 20).

To close the model for the purpose of simulations, we employ an adaptive expectations formation process (equation 4 on page 20) using parameters estimated from the stable inflation period and a 2 percent inflation target.[50] As previously indicated, basing the inflation expectations formation process on the stable inflation period is consistent with assuming that the Fed did *not* lose its anti-inflation reputation after the pandemic despite the surge of inflation. The practical implication is that changes in actual inflation have little impact on expected inflation, reducing (but not eliminating) the cost of disinflation when inflation jumps.[51]

We also estimate a Beveridge curve (equation 5 on page 23) over the 2020-22 sample and use the estimate in the v/u gap simulations to translate the v/u gap into a u gap in the Taylor Rule. While we report the results both for u gap and v/u gap models, to simplify the narrative we focus mostly on the v/u gap Hot/Cold model.

Using this setup, we simulate the path of inflation, the unemployment rate and the policy rate over the period from the fourth quarter of 2022 to the end of 2025. This allows us to address the following four questions: Does inflation return to target? What is the peak interest rate? How high does the unemployment rate go? And, related to the first and third, what is the sacrifice ratio?

Specifically, setting the controls (non-oil import price inflation and ISM manufacturing index) based on predictions from an AR(4) process, we draw 10,000 sequences of shocks from the estimated residuals for the Phillips curve and the IS curve. Each sequence yields a path of the variables of interest. To do this, both the Phillips curve and the IS curve estimates use sample periods ending in the third quarter of 2022.[52]

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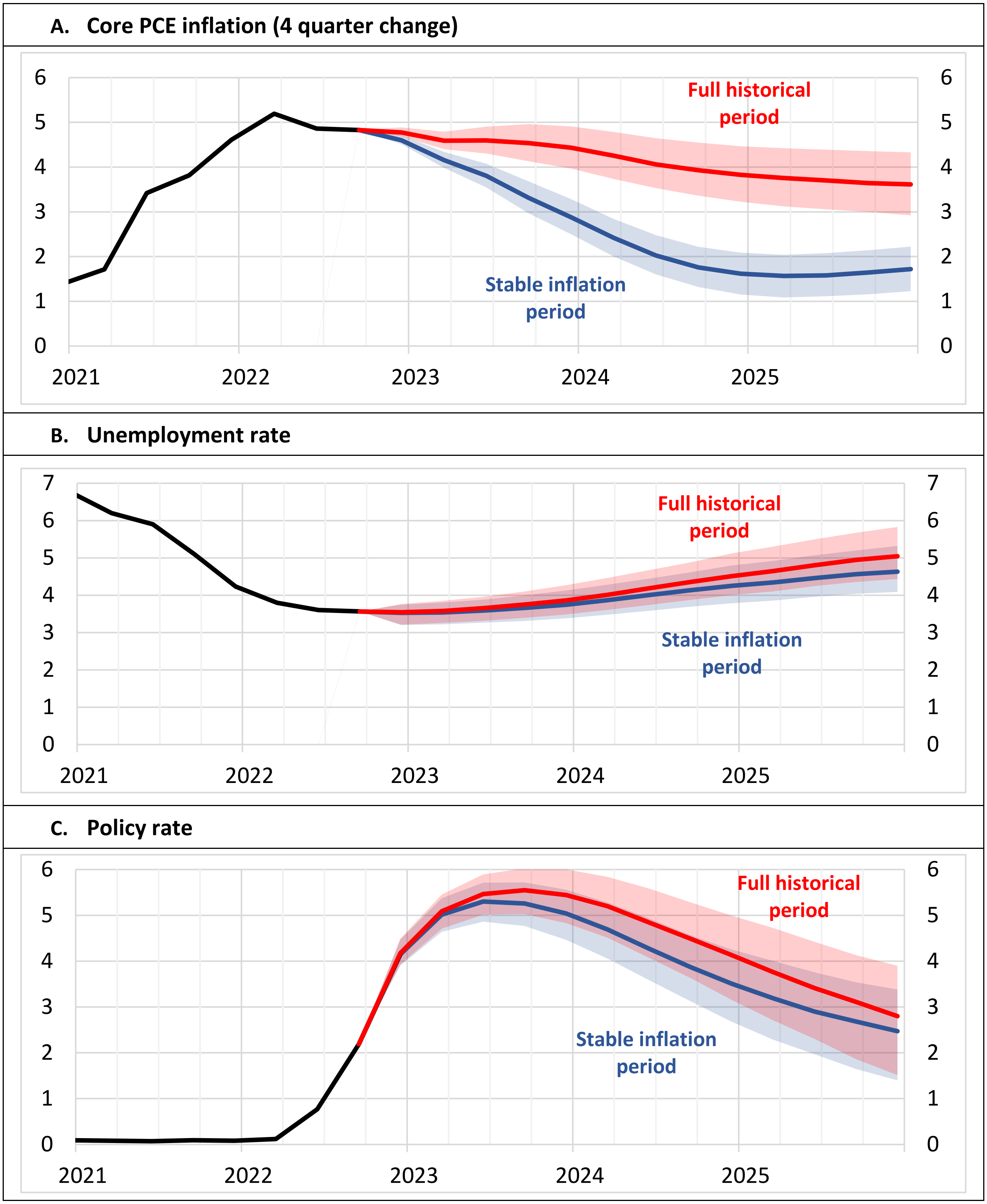
[49] See Appendix C for estimates of the parameters in the IS curve.

[50] While we address the topic of changing the inflation target in the next section, our model is *not* suitable for analyzing this change. The reason is that we construct the inflations expectations process and estimate its parameters (equation 4) on the assumption that the Fed's 2 percent inflation target is credible, and the policy regime is stable, so inflation expectations exhibit a very high degree of persistence. Even if we were to substitute a higher inflation target into this process, assuming the same high persistence would mean that inflation expectations adjust far too slowly. To put it differently, were the Fed to announce a credible increase of their inflation target, we would expect a discontinuous upward shift of inflation expectations, but this jump is something that our model would never produce. Finally, as we note in our discussion of the Volcker disinflation, the Federal Reserve's 2022 shift to aggressively policy rates appears to have helped stabilize inflation expectations. Accordingly, using a specification for inflation expectations from the stable inflation period seems warranted.

[51] In the 2022 USMPF report, Carpenter et.al. (2022) illustrate the extremes to which the costs of disinflation could rise if inflation expectations were to become unanchored.

[52] For the estimated coefficients of the 1962-3Q 2022 model, see Appendix Table B.1 (which corresponds to Table 4.1). For the estimates over the 1985-3Q 2022 sample, see Appendix Table B.2 (which corresponds to Table 4.2).

Figure 5.1 Forecasts using ($v/u - v/u^*$), Hot/Cold model, percent, 4Q 2022-2025



Note: Simulations using sample ending in 2022. Figures plot the median (solid line) and interquartile range (shaded area between the 25th and 75th percentiles of the distribution) of 10,000 draws.
Source: Authors calculations based on the model described in Section 3, with Phillips curve estimates reported in Appendix A.

Figure 5.1 illustrates the results of this exercise. Each chart displays the median (solid line) and the 25th to the 75th percentile (shaded area) of the 10,000 draws for the sequence of shocks.[53] By far the most important conclusion that we draw from these results is that the differences for inflation projections arise principally from the sample period, not from altering the slack measure or from introducing nonlinearity.

For example, looking at the top panel of Figure 5.1, we see that the model using the full historical period (1962-2022) implies that inflation will fall only gradually to 3.7 percent by the end of 2025. By contrast, the model estimated over the stable inflation period (1985-2019) has inflation falling quickly to the 2 percent target in the first quarter of 2024.[54] This difference arises primarily from the differences in the persistence of inflation in the Phillips curve in the full historical period relative to that in the stable inflation period, and to a lesser extent from the differences in the estimated slopes of the Phillips curve.[55] We should note that, in contrast to the inflation projections, neither the unemployment path nor the interest rate path shows much sensitivity to the sample period.[56]

The simulations based on our preferred Phillips curve model—the v/u gap Hot/Cold version estimated over the full historical period—allow us to characterize the prospective path of policy rates (Figure 5.1 panel C). Starting with the *level* of the simulated policy rate, we see that the median (50th percentile) reaches a peak of 5.6% in the second half of 2023. At the 75th percentile and the 90th percentile (not shown), the simulated policy rates rise further to 6.0% and 6.5%, respectively. Importantly, even in the cases where interest rates are high, inflation remains *above* the Fed's 2 percent at the end of 2025. (The 10th percentile of the distribution of inflation outcomes, which we do not show in Figure 5.1, is 2.4 percent.)

Regarding the *range* of the simulated policy rates, the outcomes widen notably with the simulation horizon. For example, at the end of 2023, the interquartile range (between the 25th and 75th percentiles) of the policy rate (shaded in pink in Figure 5.1 panel C) already is 1.2 percentage points. By the end of 2025, this gap doubles to 2.4 percentage points. Not surprisingly, the ranges of the inflation and unemployment rate simulations also widen over time, but typically less than the range of policy rate simulations.

Before continuing, we should note the consequences of our assumption regarding policy inertia in the Taylor rule (equation 2 on page 20). Over the stable inflation period, interest rate policy exhibited substantial inertia, consistent with a partial adjustment coefficient of 0.85 in the rule. In our simulations, we use 0.5, rather than 0.85. Experiments with the higher value give the expected result: the path of interest rates rises less steeply and peaks later at a lower level. To see the difference, note that our baseline simulation using the full historical period (the red line Figure 5.1 panel C) shows the policy rate peaking at 5.5 percent in the third quarter of 2023. Substituting the higher inertia of the stable inflation

[53] We note that the size of the shocks during and after the pandemic were relatively large, so the uncertainty of near-term projections may be larger than implied in Figure 5.1.
[54] While we do not report them here, inflation projections from the other models—those with other measures of slack and different functional specifications—also are far more similar to each other *within* each sample period than the differences that arise for the same specification across sample periods.
[55] We can see this by comparing the estimates reported in Tables 4.1 and 4.2. First, the coefficients on the slack variables in the full sample are larger than those for the post-1985. Second, the weight on lagged inflation in the longer sample is substantially higher.
[56] This is likely a result of the fact that the estimates of the coefficients in the IS curve (equation 1) are very similar across the sample periods.

period, the policy rate peaks one year later (in the third quarter of 2024) at 4.4 percent. Unsurprisingly, the higher the inertia in the policy rate, the slower inflation falls.[57]

Turning to a broader comparison, we compute sacrifice ratios across all eight of the gap models. Specifically, we compute the change in the unemployment rate from the fourth quarter of 2022 to the fourth quarter of 2025 divided by the change in inflation over the same period.[58] Table 5.1 reports the results.[59] Starting with the top panel where the models are estimated over the full sample, inflation falls to between 2.9 percent and 3.7 percent by the end of 2025, the unemployment rate rises to 5.1 percent, and the policy rate peaks at between 5.2 and 5.5 percent. The resulting sacrifice ratios are in the range of 0.8 to 1.4, similar to what we report for the U.S. historical episodes in Table 2.2. We note that these estimates are consistent with the ones that Tetlow (2022) obtains for the case in which inflation expectations are anchored.

Using models estimated over the 1985-2022 period yields starkly different results. These are in the bottom panel of Table 5.1. Here we see that inflation falls to or below the target of 2 percent, unemployment rises to a more modest 4.6 percent, and interest rates go to only 4.7 percent in two of the cases. These quite favorable outcomes, which result from the weaker persistence of inflation shocks, lead to sacrifice ratios of only 0.4. As we emphasize throughout, *the sample period is far more important than the specifications of the Phillips curve*.[60]

Table 5.1 Sacrifice ratio estimates: Various models and sample periods

Phillips curve model	**Full historical period** (1962-3Q 2022)			
	Peak policy rate	**π (4Q 2025)**	**u (4Q 2025)**	**Sacrifice ratio**
Linear u gap	5.2	3.2	5.1	1.0
u gap Hot/Cold	5.2	2.9	5.1	0.8
Linear v/u gap	5.5*	3.4	5.0	1.0
v/u gap Hot/Cold	5.6*	3.7	5.1	1.3
	1985-3Q 2022			
Linear u gap	4.7	2.1	4.6	0.4
u gap Hot/Cold	4.7	2.1	4.6	0.4
Linear v/u gap	5.3	1.8	4.6	0.4
v/u gap Hot/Cold	5.3	1.9	4.6	0.4

Note: The peak interest rate occurs in 2Q 2023, except for those that are starred (*), which peak in 3Q 2023. Rounding makes many of these numbers appear identical, but they are not.
Source: Median of 10,000 simulated paths using various Phillips curve models.

[57] One could examine a Fed return to gradualism by raising the inertia coefficient over the simulation period, but any assumed path for raising this coefficient would be arbitrary.

[58] Specifically, we compute $S = -(u_{4Q2025} - u_{4Q2022}) / (\pi_{4Q2025} - \pi_{4Q2022})$. As we note in footnote 12, this differs from the computation in section 2. There we compute the changes in *trend* inflation and in *trend* unemployment over the entire disinflation episode, which may not be coincident for the two variables.

[59] Note that our use of the unemployment rate means that these estimated sacrifice ratios are roughly one-half what they would be if we were to use output.

[60] Appendix B reports results analogous to Figure 5.1 and Table 5.1 based on samples ending in 2019.

6 Implications of changing the inflation target

As we have discussed, lowering the inflation rate to the Federal Reserve's target of 2 percent likely will be costly. Indeed, as we saw in Figure 2.7, the costs of pushing inflation lower could rise nonlinearly as the Fed draws closer to its objective. One seemingly simple way of reducing the cost of disinflation is to raise the target above 2 percent, thereby requiring less tightening of monetary policy to achieve the higher target. Thus, not surprisingly, there are recent, renewed calls for the Federal Reserve to raise its target from 2 percent to 3 percent or 4 percent.[61] Here we discuss the pros and cons of raising the Fed's inflation target. To be clear before starting, none of the 19 FOMC participants has voiced support for such a change.

A. Benefits of raising the inflation target

Besides lowering the cost of disinflation in the current circumstances, the most important argument for raising the Fed's inflation target is that a higher long-run target reduces the frequency and duration of episodes when the zero-lower-bound (ZLB) constraint for the policy interest rate is binding.[62] At the ZLB, if policymakers still wish to stimulate the economy, they must employ other policy tools such as large-scale-asset purchases or forward guidance. Unease about the effectiveness of these alternative policies and, in the case of asset purchases, difficulties in returning balance sheets to their original size suggests that episodes when the ZLB binds are costly.[63]

Proposals for a higher inflation target initially surfaced more than a decade ago: the goal was to provide central banks with more room to lower interest rates to counter recessions.[64] With a credible 2 percent inflation target, the ZLB implies that the lowest real policy rate that a central bank can obtain in equilibrium is –2 percent, which equals the floor of zero percent for the policy rate minus the 2 percent expected inflation. With a higher inflation target, say 4 percent, the central bank now has more room to pursue expansionary conventional monetary because it can lower the real policy rate to –4 percent, rather than –2 percent when the inflation target is 2 percent.

Research prior to the global financial crisis took the view that as long as the inflation objective was around 2 percent, then the ZLB probably would bind the policy rate only infrequently and for short periods.[65] There are two reasons why this research was too optimistic. First, it was conducted with models that were essentially linear. Yet, the global financial crisis and the COVID episode both point to greater nonlinearity in the behavior of the economy than earlier models supposed. Large negative shocks can tip the economy over a cliff, resulting in more frequent ZLB episodes of longer duration. As a

[61] See, for example, Blanchard (2022) and Bloesch (2022).

[62] Because central banks in Europe and Japan have found that the policy rate can be driven slightly below zero, the *zero*-lower bound constraint is more accurately referred to as the *effective*-lower-bound constraint. However, because the Federal Reserve has doubted that driving the federal funds rate below zero would be beneficial, here we describe the constraint as being a ZLB constraint.

[63] Greenlaw et al (2018) express skepticism about the impact of Federal Reserve balance sheet policy. Cecchetti et al (2020) argue that central bankers should be humble about the likely effectiveness of both forward guidance and balance sheet policies. For a discussion of the recent dynamics of central bank balance sheets see Cecchetti and Schoenholtz (2021).

[64] For a discussion see Blanchard, Dell'Ariccia, and Mauro (2010).

[65] Reifschneider and Williams (2000) and Coenen, Orphanides and Wieland (2004).

result, the Federal Reserve has been compelled to employ alternative monetary policy tools from 2008 to 2017, and again from 2020 to 2022.

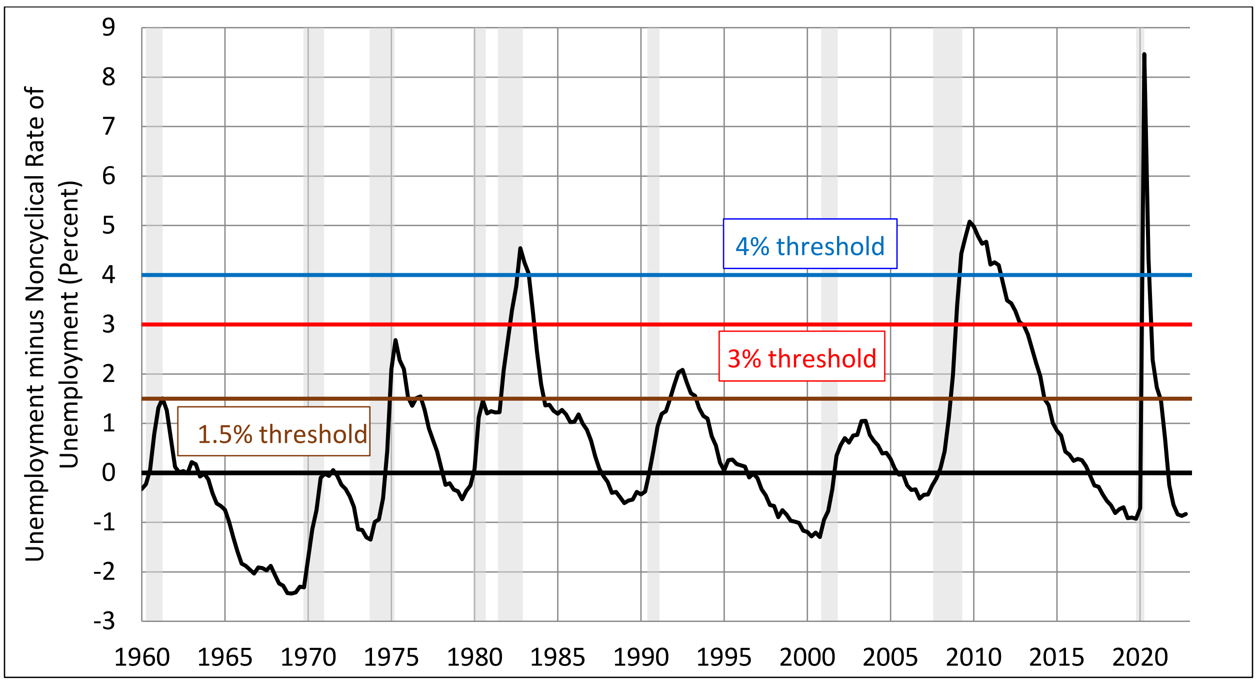
The second reason is the decline of the natural rate of interest (r^*)—that is, the equilibrium real interest rate at which the economy is at full employment with no tendency for inflation to rise or fall.[66]

Low r^* adds markedly to the risk that policy rates will fall to a floor of zero.[67] For example, consider a modified Taylor rule which responds one-for-one to the unemployment gap: [68]

$$(9)\quad i = (r^* + \pi^e) + 0.5(\pi - \pi^*) - (u - u^*) \, .$$

In equilibrium, inflation and expected inflation are at the 2 percent target ($\pi = \pi^e = \pi^* = 2$) and the unemployment rate is at its noncyclical level ($u = u^*$). As we can see from equation (9), this means that, when r^* falls from 2 percent to 1 percent, the *nominal* equilibrium rate of interest $(r^* + \pi^*)$ falls by 1 percentage point from 4 percent to 3 percent. Now there is less room for monetary policy to cut rates to stimulate demand because the policy rate can be lowered by only 3 percentage points, rather than 4, before the ZLB binds.

Figure 6.1: U.S. unemployment gap (percentage points), 1960-2022



Source: FRED.

Figure 6.1 highlights the importance of both r^* and the Taylor rule specification. With r^* and π^* both equal to 2 percent, when the unemployment rate is 4 percentage points higher than the natural rate of

[66] Holston, Laubach and Williams (2017) document the U.S. and international decline of *r** in recent years.
[67] The Federal Reserve Bank of Richmond publishes estimates of *r** based on a model of Lubik and Matthes (2015). See https://www.richmondfed.org/research/national_economy/natural_rate_interest.
[68] For a discussion of the modified Taylor rule see Cecchetti and Schoenholtz (2018). This modified Taylor rule differs from the one in equation 2 both because the coefficient on the unemployment gap is 1, rather than 2, and because it lacks policy rate smoothing.

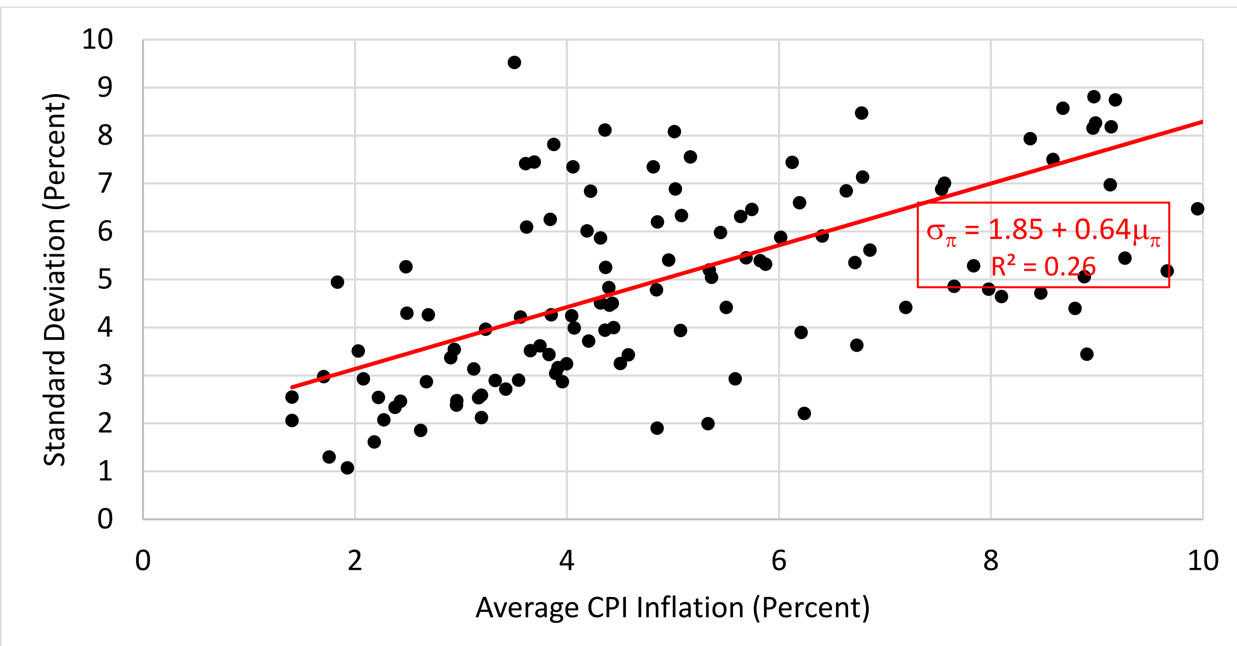
unemployment (u-u*=4), the modified Taylor rule (equation 9) indicates that the policy rate should be lowered to zero, so the ZLB binds. Figure 6.1 shows that, since 1960, the unemployment gap exceeded this 4 percent threshold (the horizontal blue line) 6 percent of the time. If r* falls from 2 percent to 1 percent, the unemployment gap threshold declines to 3 percent (the horizontal red line), a level that was surpassed nearly 10 percent of the time.

If instead we use the Fed's balanced approach rule, in which the policy rate moves two-for-one with the unemployment gap, the coefficient on (u-u*) in equation (9) is two instead of one. In this circumstance, an r* of 1 percent implies a threshold for the unemployment gap of a mere 1½ percent (the horizontal brown line). Since 1960, the unemployment gap exceeded this level nearly 20 percent of the time.[69]

B. Costs of raising the inflation target

Raising the inflation target entails two key long-run costs. First, there is the potential for increased uncertainty that can make household and business decisions less efficient. Indeed, economists have long observed a correlation between the *level* and the *volatility* of inflation, with the latter serving as a proxy for uncertainty. For a sample of more than 120 countries with average inflation up to 10 percent, Figure 6.2 below shows that a one-percentage point addition to average inflation is associated with a 0.64-percentage-point rise in the annual standard deviation of inflation. Theoretical analysis shows that increases in trend inflation naturally lead to greater volatility in a standard macro model.[70]

Figure 6.2: Annual CPI inflation versus standard deviation of annual inflation, 1970-2021



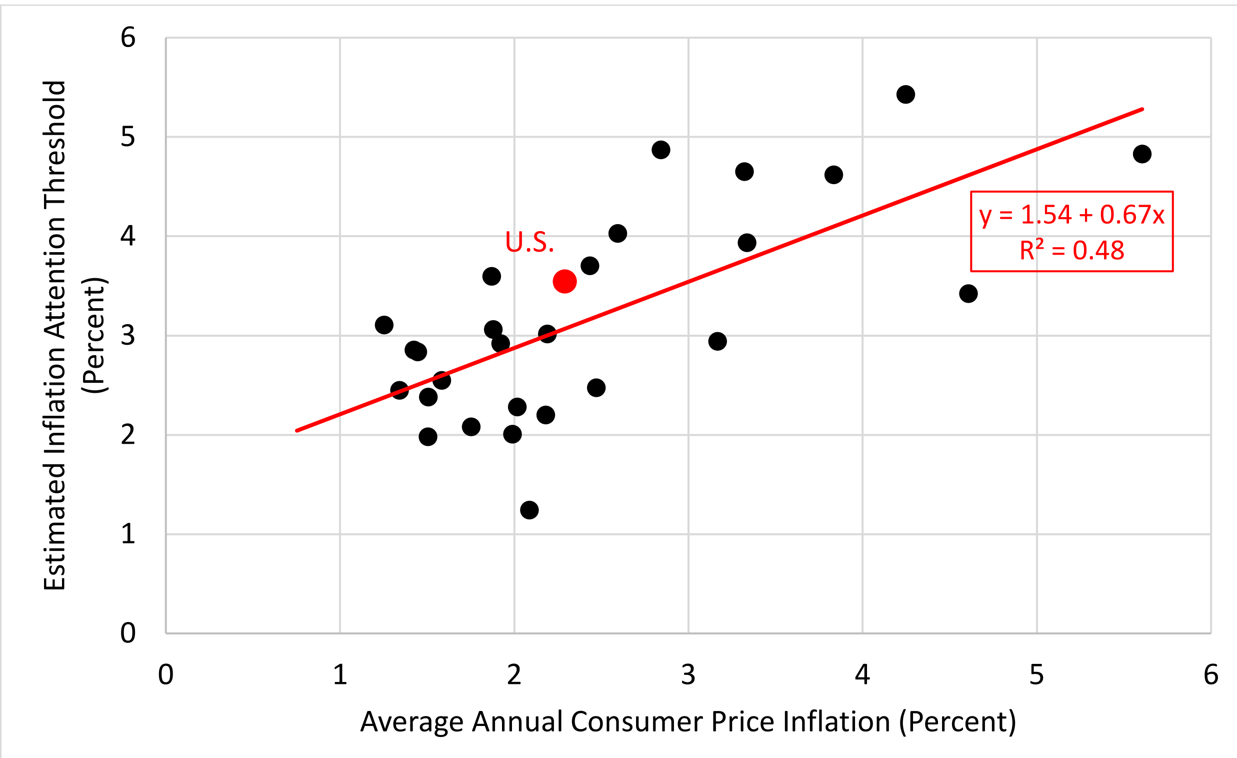
Note: The sample of 121 countries includes those with average inflation up to 10 percent and with at least 10 annual observations. Three outliers are not depicted. The red line is a linear fit of the data, with the regression shown in the box. Source: World Bank (FP.CPI.TOTL.ZG).

[69] Using the FRB/US model and the Fed's balanced approach Taylor rule, Kiley and Roberts (2017) estimate that the U.S. economy would hit the ZLB nearly 40 percent of the time. See their Table 3.
[70] See Coibion et. al. (2012).

Second, there can be behavioral costs associated with raising the inflation target. Former Federal Reserve Chair Alan Greenspan provided a "rational inattention" definition of price stability, describing it as the "state in which expected changes in the general price level do not effectively alter business or household decisions."[71] Both theory and evidence suggest that as inflation rises above the Greenspan definition, people eventually will respond with increased sensitivity.[72] This, in turn, will drive up inflation expectations, making it more difficult and more costly for the central bank to achieve its target. That is, when inflation rises sufficiently, people start to pay attention.

Korenok, Munro and Chen (2022) provide evidence on when the Greenspan attention threshold is reached. Using the frequency of online searches for the word "inflation" as a proxy, they estimate country-by-country attention thresholds beyond which behavior changes. Figure 6.3 (which reproduces their Figure 8) plots the estimated thresholds against each country's average level of inflation. On average, a one-percentage-point increase in average inflation is associated with a 0.67-percentage point rise in the attention threshold.

Figure 6.3: Estimated inflation attention thresholds and average inflation, 2004-May 2022



Source: Figure 8 in Korenok, Munro and Chen (2022). The figure includes those 28 out of 37 countries in the Google Trends sample where the estimates showed either no or little inflation sensitivity of online search activity *below* the estimated threshold and marked sensitivity of search activity *above* that level. We thank Oleg Korenok, David Munro, and Jiayi Chen for graciously providing their data.

Korenok, Munro and Chen (2022) and others emphasize the importance of keeping inflation targets below the level that triggers attention as this poses a risk that inflation expectations will rise. While their

[71] See page 53 of Federal Open Market Committee (1996).
[72] See, for example, Bracha and Tang (2022).

U.S. point estimate of 3.55 percent (red circle in the chart) would seem to offer space to raise the inflation target above 2 percent, we worry that this is illusory. Instead, looking at the cross-country evidence, it appears that as households and businesses become *accustomed* to higher average inflation, their attention threshold rises. Knowing this, however, people may well come to expect that a central bank with discretion will raise its inflation target repeatedly to exploit the observed inattention gaps as attention thresholds climb.[73]

Finally, the recent rise in inflation has increased interest in its distributional impact. For example, Jayashankar and Murphy (2023) cite the results of a recent U.S. Census Bureau survey, which found that elevated inflation hits the real incomes of lower income households, whose expenditures are skewed more heavily toward food, fuel, and rent, disproportionately relative to higher income households. Lee, Macaluso, and Schwartzman (2022) find that, in assessing the impact of easy monetary policy, the real income losses to minority households associated with increased inflation significantly exceed the gains from unemployment reductions. In brief, the weight of evidence has been coming down against raising the inflation target on the grounds of enhancing economic equity.

C. Time inconsistency of raising the inflation target

If the inflation target were to be raised from its 2 percent level, the time inconsistency problem arises. Once inflation rises significantly and persistently above this level, the public is likely to believe that price stability is no longer a credible goal. Then, as former Federal Reserve Chair Ben Bernanke put it, *"*Folks would say, well, if we go to 4 percent, why not go to 6 percent. It'd be very difficult to tie down expectations to 4 percent.*"*[74]

Indeed, there are parallels with the experience in the United States from the 1960s to the 1980s. At the beginning of the 1960s, inflation was below 2 percent and policymakers believed that they could lower the unemployment rate if they were willing to tolerate inflation in the 4 to 5 percent range. However, when inflation rose above 3 percent, it kept on rising, leading to the so-called Great Inflation period. As we discussed in the case study of Section 2, reducing inflation back down to 2 percent was then very costly.

No central banker wants to go through that again. Indeed, one of the great successes of central banks in many countries over the past 30 years is the anchoring of inflation expectations near 2 percent. Raising the inflation target could jeopardize this hard-earned success, with the result that the economy would lose the credible nominal anchor that has been so crucial to its health.[75]

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[73]We note that there is little empirical evidence to support one of the most widely cited costs of higher inflation: namely, that higher inflation increases cross-sectional price dispersion, reducing the efficient allocation of resources. Indeed, recent research finds *no* evidence that U.S. price dispersion was greater in the high-inflation period of the late 1970s. Instead, an increased *frequency* of price changes in periods of higher inflation limited inefficient price dispersion even as the *magnitude* of price adjustments was stable over decades. See Nakamura, et al. (2018).

[74] See Wessel (2018).

[75] Limiting the "inflation expectations ratchet"—avoiding perceptions of opportunistic central bank discretion—requires a governance framework that allows for a shift in the target only when conditions truly warrant. One solution is to give elected officials a key role in setting inflation targets. Examples of such constrained central bank governance include the mechanisms in the United Kingdom and New Zealand, where under a parliamentary system, the government sets the specific numerical target for inflation. See https://www.bankofengland.co.uk/monetary-policy/inflation and

D. Conclusions on raising the inflation target

While raising the inflation target could reduce the costs of lowering inflation to its now-higher target and lower the frequency and duration of ZLB episodes, we believe that the costs far outweigh the benefits. An important point is that the efficiency costs of a higher inflation target discussed above are permanent, while the benefits of a higher inflation target accrue only in the short run amid a deep recession. Thus, even if the efficiency costs are not terribly large in any given year, they keep adding up and probably become larger in present value terms than the intermittent benefits obtained easing the ZLB constraint.

If the inflation target were being chosen from scratch today, now that *r** has fallen and we know that the economy is vulnerable to large negative shocks, then a somewhat higher inflation target—say, 3 percent—might be consistent with the Greenspan definition of price stability. The authors of this paper have not sought to reach agreement on whether such a higher inflation target is now warranted, let alone on what the optimal level of inflation is.

Nonetheless, there is an important timing issue which suggests that raising the inflation target today would be a serious mistake. The concern is that raising the inflation target when inflation is above the target produces undesirable expectations dynamics.[76] When a central bank accepts inflation persistently above target, the resulting increase in *expected* inflation lowers the real interest rate for a given level of the nominal policy rate. The effect is to stimulate the economy. This can produce an adverse feedback loop: namely, a shock that raises inflation also raises inflation expectations and lowers the real interest rate, thereby stimulating the economy and adding further to upward inflation pressure. These perverse expectations dynamics are the flip side of the adverse feedback loop discussed by Eggertsson and Woodford (2003), who considered the opposite impulse of a negative shock to inflation that reduces expected inflation, raises the real interest rate, restrains the economy, lowers inflation further, and so on.

Another argument for not raising the inflation target when inflation is above the target is that it would suggest that the central bank is giving up on its commitment to the target when it is convenient to do so. Such an opportunistic central bank would then be operating in a discretionary manner that severely undermines the credibility of the inflation target.

Our conclusion from this reasoning is that central banks should consider raising the inflation target only when inflation is low, and not when it is well above target. Clearly, that is *not* the situation now, where the inflation rate is projected to be above the 2 percent target for several years. Put differently, even if there is a case for the Fed to consider whether the optimal level of inflation exceeds 2 percent, now is decidedly not the time.

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https://www.imf.org/external/pubs/ft/seminar/2000/targets/archer.htm. However, in the United States, the co-equal status of the executive and legislative branches complicates rules for constraining central bank discretion. The Federal Reserve could follow an approach that it now employs regarding the possible introduction of a central bank digital currency: namely, the Fed could *announce* that it will *not* alter its inflation target without the explicit support of *both* the legislative and executive branches, ideally in the form of legislation. See, for example, Cecchetti and Schoenholtz (2022).

[76] See Mishkin (2008).

7. Conclusions

Our analysis of managing disinflation leads to a number of conclusions that we group into three categories: historical evidence, inflation modelling and policy implications.

A. Historical evidence

- Significant disinflations induced by monetary policy tightening are associated with recessions. More specifically, all the 16 large policy-induced disinflations in our sample of four advanced economies since 1950 are associated with a recession. Hence, in the current circumstances that already involve significant policy tightening (and a prospect for further restraint), an "immaculate disinflation" would be unprecedented.

- The historical record points to nonlinearities in the inflation process, but these are difficult to measure precisely and may evolve over time. As one example, the presence of a very tight labor market can partly account for the 2021-22 surge of inflation. Regarding the management of disinflation, there are two apparent nonlinearities. First, we find a negative relationship between the sacrifice ratio and the starting point for inflation. Put differently, a lower initial level of inflation tends to be followed by a higher cost of lowering inflation by one percentage point. Second, we see that faster disinflations involve less sacrifice.

- Only when inflation was close to target and there were no large adverse supply shocks, has preemptive monetary policy tightening been able to keep inflation in check without inducing a recession.

- The Volcker disinflation demonstrates that—even if the sacrifice ratio is modest—a large disinflation has large costs. It also teaches us that easing policy too early or by too much, before disinflation is complete, increases cumulative costs.

B. Inflation Modelling

- Estimates using data starting in the 1960s exhibit a greater persistence of inflation shocks, as well as a greater sensitivity of inflation to slack, than do models estimated over the Great Moderation period from 1985 to 2019.

- Our preferred model, estimated using data starting in the 1960s, indicates that a hot labor market raises inflation, but a cold labor market does not lower inflation.

- Models estimated using data that include the high and volatile inflation episodes of the 1960s and 1970s do a better job of tracking the rise in inflation in recent years. A key reason is that the inflation expectations process prior to 1985 has a much larger backward-looking component, consistent with a lack of monetary policy credibility. While the estimation period is a more consequential factor for predicting inflation, inflation models that are nonlinear in slack measured by the v/u gap, rather than the u gap, also perform better.

- Combined, our model estimates suggest that the preemptive monetary policy strategy that prevailed in the period from 1985 to early 2020 biases estimates of the Phillips curve slope toward zero.

C. Policy implications

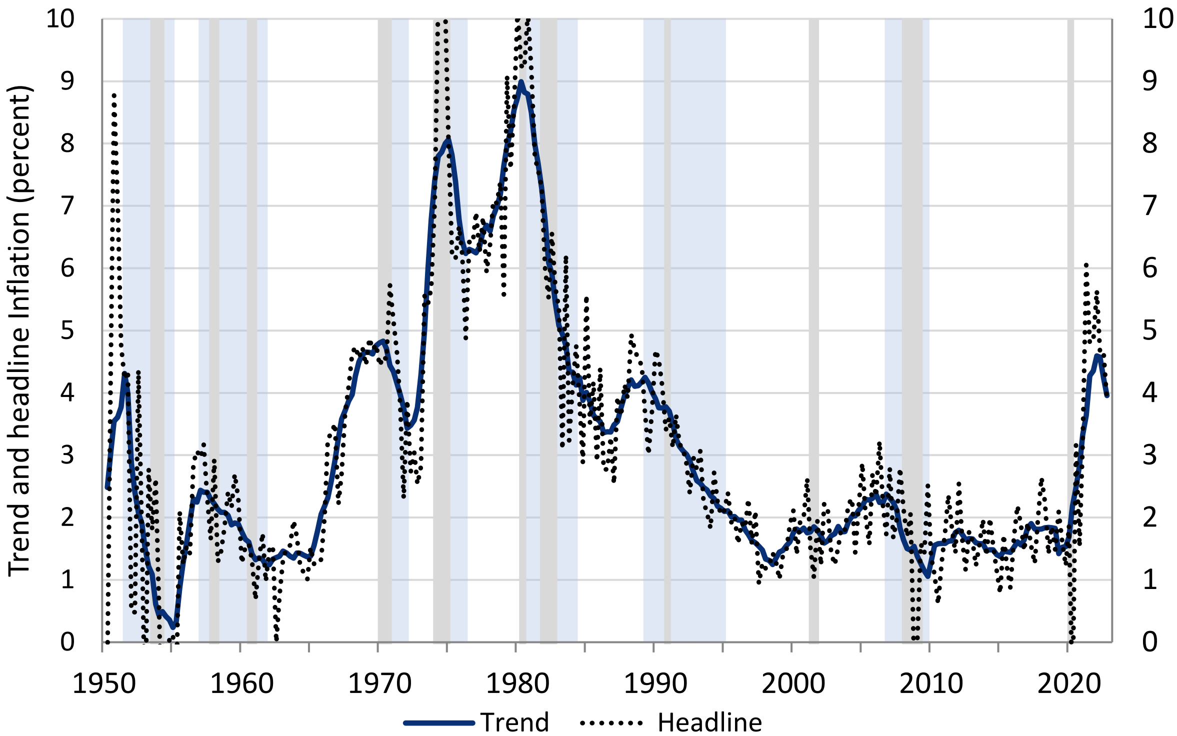
- The historical evidence and modelling exercises suggest that additional monetary tightening and greater labor market slack will be needed for the Fed to reach its 2% inflation goal by 2025. They also suggest that achieving the target over this horizon will entail at least a mild recession.
- The key role of the sample period in estimates of inflation models, along with the result that a cold labor market does not lower inflation, favors preemption as a monetary policy strategy for maintaining price stability and lowering the cost of disinflations.
- The link between speedy disinflations and low sacrifice costs favors less gradualism and more aggressive policy when a central bank wishes to bring about a large disinflation.

Based on this analysis, in retrospect, we view the Fed's failure to act preemptively in 2021 in the face of strong demand as a significant error. However, its abandonment of gradualism in 2022 helped stabilize inflation expectations.

Going forward, provided policymakers maintain a restrictive stance through 2023 and possibly beyond, the Fed appears to be on track to approach the 2% inflation target within a reasonable horizon. As Chair Powell (2022) argued, the cost of premature easing likely would be high and, in our view, higher than the cost of temporarily excessive policy restraint. At the same time, our historical analysis and modelling exercise lead us to conclude that the Federal Reserve and other key central banks will find it difficult to achieve their disinflation goals without a significant sacrifice in economic activity.

Appendix A: Notable U.S. disinflation episodes

Figure A.1 Notable U.S. disinflation episodes: Core PCE, quarterly, 1950-2022



Notes: The trend line is extended to 4Q 2022 using quarterly projections from the January 2023 Bloomberg survey of professional forecasters. These consensus forecasts show a decline similar to the median annual projections in the December 2022 FOMC Summary of Economic Projections. Inflation is at an annual rate in percent.
Source: Bloomberg, BLS and authors' computations.

Appendix B: Phillips curve estimates with data through 3Q 2022

This appendix reports estimates of Phillips curves using samples from 1962 to 3Q 2022 (Table B.1) and 1985 to 3Q 2022 (Table B.2). These two tables correspond to Tables 4.1 and 4.2 in the text. Furthermore, these estimates are the basis for the simulations in Section 5.

Table B.1: Phillips curve: Alternative specifications, core PCE inflation, 1962-3Q 2022, quarterly

		Measure of Slack					
		$(u\text{-}u^*)$			$(v/u - v/u^*)$		
		Linear	Cubic	Hot/Cold	Linear	Cubic	Hot/Cold
		(1)	(2)	(3)	(4)	(5)	(6)
Linear	Slack (γ_0)	0.009 (0.46)			0.119 (0.58)		
Cubic	Slack (γ_1)		-0.080 (0.12)			0.704 (0.02)	
	Slack^2 (γ_2)		0.004 (0.86)			0.922 (0.09)	
	Slack^3 (γ_3)		0.004 (0.18)			-1.993 (0.02)	
	Slope (Hot)		-0.072 (0.43)			0.408 (0.26)	
	Slope (Cold)		0.049 (0.38)			-0.891 (0.12)	
Piecewise Linear	Hot (λ_1)			-0.146 (0.12)			0.376 (0.32)
	Cold (λ_2)			-0.049 (0.36)			-0.150 (0.67)
Lagged inflation	$\sum_{j=1}^{4}\beta_j\pi_{t-j}^{core}$	0.883 (0.00)	0.870 (0.00)	0.859 (0.00)	0.864 (0.00)	0.890 (0.00)	0.849 (0.00)
Controls	$\sum_{j=1}^{4}\delta_j\pi_{t-j}^{imp}$	0.008 (0.60)	0.010 (0.50)	0.013 (0.41)	0.009 (0.56)	0.006 (0.69)	0.012 (0.47)
	$\sum_{j=1}^{4}\phi_j ISM_{t-j}$	0.045 (0.00)	0.037 (0.00)	0.040 (0.00)	0.042 (0.00)	0.038 (0.01)	0.039 (0.01)
	R^2	0.703	0.713	0.706	0.703	0.711	0.705

Note: Values in parentheses are p-values; $p<0.01$, $p<0.05$, $p<0.10$

Table B.2: Phillips curve: Alternative specifications, core PCE inflation, 1985-3Q 2022, quarterly

		Measure of Slack					
		$(u\text{-}u^*)$			$(v/u - v/u^*)$		
		Linear	Cubic	Hot/Cold	Linear	Cubic	Hot/Cold
		(1)	(2)	(3)	(4)	(5)	(6)
Linear	Slack (γ_0)	0.060 (0.12)			-0.177 (0.38)		
Cubic	Slack (γ_1)		0.066 (0.47)			-0.175 (0.65)	
Cubic	Slack^2 (γ_2)		-0.039 (0.33)			0.031 (0.96)	
Cubic	Slack^3 (γ_3)		0.007 (0.08)			0.014 (0.99)	
Cubic	Slope (Hot)		0.145 (0.37)			-0.157 (0.74)	
Cubic	Slope (Cold)		0.034 (0.62)			-0.196 (0.81)	
Piecewise Linear	Hot (λ_1)			0.022 (0.90)			-0.091 (0.86)
Piecewise Linear	Cold (λ_2)			0.065 (0.15)			-0.221 (0.51)
Lagged inflation	$\sum_{j=1}^{4} \beta_j \pi_{t-j}^{core}$	0.675 (0.00)	0.674 (0.00)	0.674 (0.00)	0.654 (0.00)	0.650 (0.00)	0.647 (0.00)
Controls	$\sum_{j=1}^{4} \delta_j \pi_{t-j}^{imp}$	-0.030 (0.11)	-0.026 (0.17)	-0.029 (0.12)	-0.030 (0.10)	-0.030 (0.11)	-0.030 (0.11)
Controls	$\sum_{j=1}^{4} \phi_j ISM_{t-j}$	0.071 (0.00)	0.063 (0.00)	0.071 (0.00)	0.076 (0.00)	0.076 (0.00)	0.075 (0.01)
	R^2	0.558	0.570	0.558	0.550	0.550	0.551

Note: Values in parentheses are p-values; $p<0.01$, $p<0.05$, $p<0.10$

Appendix C: IS curve estimates

In this appendix we report the estimates of the IS curve, equation (1), for our baseline v/u gap model estimated over various sample periods.

(1) $$(u_t - u_t^*) = \sum_{k=1}^{2} \phi_k (v/u \text{ gap})_{t-k} + \frac{\kappa}{4}\left[\sum_{m=1}^{4}(i_{t-m} - \pi_{t-m}^e) - r_{t-m}^*\right] + \varepsilon_{IS,t}$$

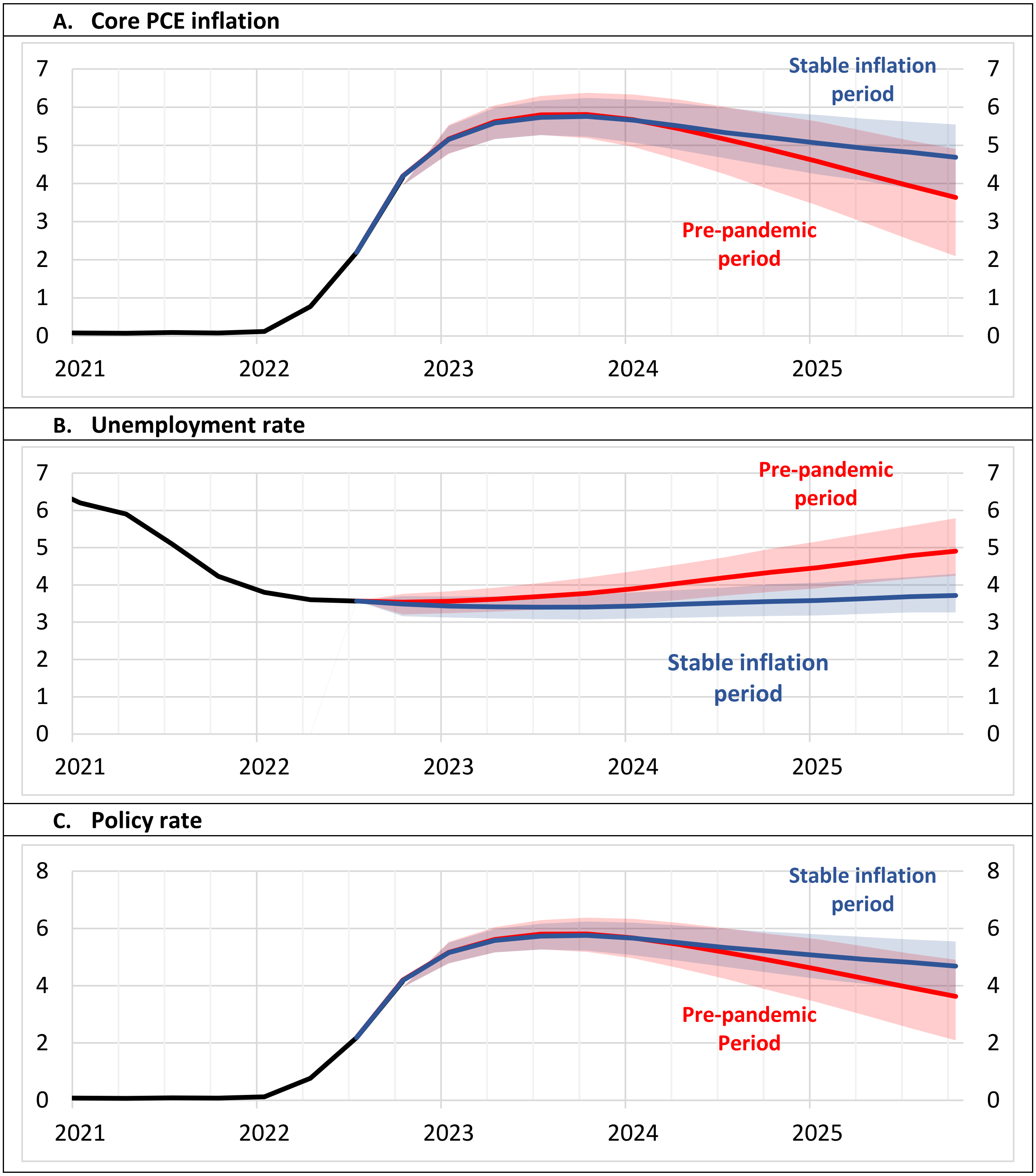
	Sample Period			
	1962-2022	1985-2022	1962-2019	1985-2019
Slack $\sum_{k=1}^{2}\phi_k$	0.968 (0.00)	0.981 (0.00)	0.979 (0.00)	1.015 (0.00)
Real interest rate gap (κ)	-0.008 (0.05)	-0.009 (0.32)	-0.006 (0.00)	-0.009 (0.00)
R^2	0.956	0.938	0.978	0.980

Source: Estimate of equation (1).

Appendix D: Simulation results using estimates through 2019

In this appendix we present the results for simulations using the model estimating over the pre-pandemic (1962-2019) sample.

Figure D.1 Forecasts using (*v/u – v/u), Hot/Cold model, percent, 4Q 2022-2025**



Note: Simulations based on models estimates using samples ending in 2019 sample. Figures plot the median and interquartile range of 10,000 draws.

Source: Authors calculations based on the model described in Section 3, with estimates reported in Tables 4.1 and 4.2.

Table D.1: Sacrifice ratio estimates: Various models and sample periods

Phillips curve model	**Pre-pandemic period** (1962-2019)			
	Peak policy rate	π **(4Q 2025)**	u **(4Q 2025)**	**Sacrifice ratio**
Linear *u* gap	5.7	3.4	5.2	1.3
***u* gap Hot/Cold**	5.7	3.3	5.2	1.2
Linear *v/u* gap	5.7	4.1	4.9	2.0
***v/u* gap Hot/Cold**	5.8*	4.6	4.9	6.3
	Stable inflation period (1985-2019)			
Linear *u* gap	5.4	2.1	4.7	0.5
***u* gap Hot/Cold**	5.4	2.2	4.7	0.5
Linear *v/u* gap	5.6	2.0	3.7	0.1
***v/u* gap Hot/Cold**	5.8	2.7	3.7	0.1

Note: The peak interest rate occurs in 3Q 2023, except for those that are starred (*), which peak in 4Q 2023.
Source: Median of 10,000 simulated paths using various Phillips curve models.

Appendix E: Data sources

Data were obtained from Haver Analytics in most cases. Haver source codes are provided in brackets.

United States

CPI:

Consumer Price Index for All Urban Consumers: All Items in U.S. City Average, seasonally adjusted, monthly (BLS). [PCU@USECON]

Core PCE:

1959 to 2022: Personal Consumption Expenditures Excluding Food and Energy (Chain-Type Price Index), seasonally adjusted, monthly (BEA). [JCXFEBM@USECON]

1949 to 1958: We fit a regression of Core PCE on Core CPI (Consumer Price Index for All Urban Consumers: All Items Less Food and Energy in U.S. City Average) using seasonally adjusted monthly data for the period 1959 to 2022. We then backcast the Core PCE as fitted values from this regression using the Bolhuis, Cramer and Summers (2022) measure of core CPI.

Inflation expectations (π^e):

1975 to 2022: FRB/US 10 year expected PCE price inflation (PTR) (Federal Reserve).

1960 to 1974: 40-quarter annualized change in headline PCE [JC@USECON], adjusted for the gap between the change in headline PCE and PTR in 1Q 1975 (authors' calculations).

Output Gap:

Percent deviation of Real Gross Domestic Product, seasonally adjusted, quarterly (BEA) From Potential Gross Domestic Product, seasonally adjusted, quarterly (CBO). [OGAPQ@USECON]

Unemployment gap (u-u^*):

Difference between the Civilian unemployment rate, seasonally adjusted, monthly (BLS) [LR@USECON] and the noncyclical rate of unemployment (CBO) [NAIRUQ@USECON].

Vacancies to unemployment ratio (v/u):

2001 to 2022: JOLTS ratio of vacancies [LJJTLA@USECON] to unemployment LTU@USECON], seasonally adjusted, monthly (BLS).

1950 to 2000: Barnichon (2010).

Noncyclical vacancies to unemployment ratio (v/u^*):

Computed using estimated text equation (6) (authors).

Vacancies to unemployment ratio gap:

Difference between the vacancies to unemployment ratio (v/u) and its noncyclical value (v/u^*)

Federal funds rate:

Effective federal funds rate, quarterly average (Federal Reserve) [FFED@USECON]

Neutral rate of interest (r^*):

1960 to 3Q 2020: Holston, Laubach, and Williams (2017) [NRI3D@SURVEYS]

4Q 2020 to 2022: authors set r^* at 0.5%.

ISM manufacturing suppliers' deliveries index:

Manufacturers supplier's delivery index, seasonally adjusted, monthly (Institute for Supply Management) [NAPMVDI@USECON]

Relative non-oil import prices:

The creation of the relative import prices is based on that of Peneva and Rudd (2015). First we compute the 4-quarter log difference in the price of nonpetroleum goods imports [JMMXP@USNA] (goods imports [JMMX@USNA] prior to 1968). We subtract core PCE inflation [JCXFE@USNA], and then multiply the difference by a normalized 2-quarter moving average of the ratio of nominal import prices to nominal core PCE. ([MMX@USNA] / [CX@USNA – CNFOX@USNA – CNEX@USNA]).

Other countries:

All data are from the OECD Main Economic Indicators, with the exception of the unemployment rate for Germany, which is from the Federal Statistical Office (Statistisches Bundesamt).

Canada

CPI inflation: [N156PC@OECDMEI]
Core CPI inflation: [N156PCXG@OECDMEI]
Unemployment rate: [C156LRCL@OECDMEI]

Germany

CPI inflation: [N134PC@OECDMEI]
Core CPI inflation: [N134PCXG@OECDMEI]
Unemployment rate: [DESE315@GERMANY]

United Kingdom

CPI inflation: [N112PC@OECDMEI]
Core CPI inflation: [N112PCXG@OECDMEI]
Unemployment rate: [C112LFGD@OECDMEI]

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