INTERNATIONAL MONETARY FUND

Measuring U.S. Core Inflation: The Stress Test of COVID-19

Laurence Ball, Daniel Leigh, Prachi Mishra, and Antonio Spilimbergo

WP/21/291

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2021
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WORKING PAPER

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IMF Working Paper
Research Department

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Authorized for distribution by Gita Gopinath
December 2021

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ABSTRACT: Large price changes in industries affected by the COVID-19 pandemic have caused erratic fluctuations in the U.S. headline inflation rate. This paper compares alternative approaches to filtering out the transitory effects of these industry price changes and measuring the underlying or core level of inflation over 2020-2021. The Federal Reserve's preferred measure of core, the inflation rate excluding food and energy prices (XFE), has performed poorly: over most of 2020-21, it is almost as volatile as headline inflation. Measures of core that exclude a fixed set of additional industries, such as the Atlanta Fed's sticky-price inflation rate, have been less volatile, but the least volatile have been measures that filter out large price changes in any industry, such as the Cleveland Fed's median inflation rate and the Dallas Fed's trimmed mean inflation rate. These core measures have followed smooth paths, drifting down when the economy was weak in 2020 and then rising as the economy has rebounded. Overall, we find that the case for the Federal Reserve to move away from the traditional XFE measure of core has strengthened during 2020-21.

JEL Classification Numbers:	E31, E58
Keywords:	Inflation, business fluctuations, central banks.

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* Mattia Coppo provided excellent research assistance and Jane Haizel provided excellent administrative support.

WORKING PAPERS

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Prepared by Laurence Ball, Daniel Leigh, Prachi Mishra, and Antonio Spilimbergo [1]

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I. Introduction

The unprecedented effects of COVID-19 on the economy have produced high volatility in the headline inflation rate over 2020-2021, including a sharp rise in recent months to levels not seen in decades. This experience has produced an energetic debate over how best to filter out the transitory effects of the pandemic and measure the underlying or “core” level of inflation.

This discussion is the latest installment in a broader debate about the measurement of core inflation. For decades, economists have sought a measure of core that filters out the transitory effects of large price changes in certain sectors of the economy, and is therefore less volatile than headline inflation and more closely related to macroeconomic conditions. Policymakers often say that they base their actions on movements in core rather than headline inflation (for example, Mishkin, 2007).

The most common measure of core inflation is the inflation rate excluding the prices of food and energy (XFE inflation). This measure reflects the fact that changes in food and energy prices caused large fluctuations in headline inflation during the 1970s, when the concept of core was developed (Gordon, 1975). Reflecting this legacy, statements by Fed officials often treat XFE inflation and core inflation as synonyms, and forecasts of XFE inflation are central to policy analysis by the Federal Open Market Committee (FOMC) and Fed staff.

Many researchers, however, have pointed out that volatility in headline inflation can arise from price changes in industries other than food and energy. Dolmas (2005), for example, reports that large price changes are common in industries such as computers and software, televisions, clothing, airline services, financial services, and auto insurance. An example that attracted policymakers’ attention was the 84 percent annualized fall in cell phone service prices that occurred in March 2017, when unlimited data plans were introduced (Yellen 2017).

Such experiences have led researchers to develop alternatives to XFE inflation as measures of core inflation. Some of these measures, such as the Atlanta Fed’s sticky-price inflation rate, exclude not only food and energy but also a set of other industries that typically have volatile prices. Other measures, such as the Cleveland Fed’s weighted median inflation rate and the Dallas Fed’s trimmed mean inflation rate, exclude outliers in each month’s distribution of industry price changes, regardless of which industries they are. We will use the terms “fixed-exclusion” and “outlier-exclusion” for these two classes of core measures, respectively.[2]

Economists have analyzed the performance of various core measures since alternatives to XFE inflation were first introduced in the 1990s. This paper contributes to this debate with a case study of the COVID-19 era of 2020-2021. We examine this period because the economic disruptions during the pandemic have caused extreme price movements in many industries–examples include air travel, hotels and motels, used cars, clothing, spectator sports, and financial services–and these price changes have produced erratic movements in headline inflation. If a core measure is meant to filter out transitory inflation movements arising from sectoral shocks, the COVID-19 experience has been a stress test with very large shocks.

The data yield some clear rankings of core measures in their effectiveness at filtering out the COVID-era shocks. The traditional XFE measure does quite poorly: for most of 2020-2021, it is almost as volatile as headline inflation, because most of the large industry price changes have occurred outside of food and energy. Fixed-exclusion measures of core that filter out more industries fare better than XFE, but the most successful are outlier-exclusion measures such as those developed by the Cleveland and Dallas Feds. These measures have been relatively stable because they have filtered out large price

[2] Another approach is to extract a measure of core inflation from the time series for industry inflation rates using statistical techniques such as factor analysis. The New York Fed produces one such measure. Future research could compare this approach to the ones considered in this paper.

changes in industries that are not excluded from other measures because their prices were not volatile before COVID-19.

A good measure of core inflation should move in the opposite direction from economic slack, in accord with the Phillips curve (for example, Schembri, 2017; Dolmas and Koenig, 2019). Therefore, in addition to examining the volatility of different core measures, we examine their relationship to slack as measured by the deviation of unemployment from its natural rate (as estimated by the Congressional Budget Office). Once again, over 2020-2021, outlier-trimming measures perform best: they drifted down as the economy weakened in the early part of the pandemic and then have risen as the economy rebounded. The comovement of these core variables with slack is even stronger than that of "cyclical inflation" measures developed by the San Francisco Fed and Stock and Watson (2019), which weight industries based on their historical correlation with slack.

After finding that outlier-exclusion measures of core inflation perform better than fixed-exclusion measures, we compare different measures within the outlier-exclusion class. These measures are trimmed means of the price change distribution with different amounts of trimming, including the limiting case of weighted medians, which trim the entire distribution except the midpoint. We find that the performance of different measures is similar as long as there is substantial trimming, at least 25-30 percent from each side of the weighted distribution of prices. In particular, the Dallas Fed's measure of core PCE inflation, which trims the bottom 24 percent and top 31 percent from the distribution of prices each month, has a similar level of volatility and relation to slack as the Cleveland Fed's weighted median. Less heavily trimmed means, such as another core measure from the Cleveland Fed that trims the top and bottom 8 percent from the distribution, are less effective at filtering out the volatility in headline inflation.

In the rest of this paper, we briefly review the evidence regarding core inflation before the COVID-19 crisis and then focus on what has happened over 2020-2021.

II. Pre-Pandemic Evidence on Alternative Core Measures

A substantial literature has examined the performance of core inflation measures before the COVID-19 pandemic, focusing on comparisons of outlier-exclusion measures—medians and trimmed means—to the traditional XFE measure. This work has evaluated core measures using criteria that include volatility, relation to slack, and forecasting power.[3]

Volatility

Since core measures are meant to filter out transitory movements in headline inflation, a good measure should be fairly stable over time. A number of pre-COVID-19 studies examine the volatility of alternative core variables, as measured by the variance of either the level or the change in the variable, and find that trimmed means and medians are less volatile than XFE inflation. Recent studies include Ball and Mazumder (2020) and Verbrugge (2021).

Figure 1 summarizes this evidence by reporting, for 1985-2019, the standard deviations of the headline inflation and core inflation rates as measured by XFE, trimmed mean and weighted median inflation. We examine monthly annualized seasonally adjusted inflation in both of the leading price indexes in the U.S.: the consumer price index (CPI) and the personal consumption expenditures (PCE) deflator. For both price indexes, we see that XFE inflation filters out a substantial share of the fluctuations

[3] For theoretical rationales for outlier-exclusion measures, see Bryan and Cecchetti (1994) and Ball and Mazumder (2011). These papers argue that large relative-price changes cause transitory movements in inflation in sticky-price models.

in headline inflation: its standard deviation is smaller than that of headline by about one half (1.42/3.06) for the CPI and by about one-third (1.45/2.28) for the PCE. This result reflects the fact that sectoral shocks affecting headline inflation have often occurred in energy. We also see that the standard deviation of median inflation is even lower: it is lower than that of headline by about two-thirds (1.05/3.06) for the CPI and by more than half (0.96/2.28) for the PCE deflator. The trimmed mean measures are also less volatile than XFE inflation.

Relation to Slack

According to the Phillips Curve, core inflation should move in the opposite direction from economic slack. A number of studies, including those cited above and Dolmas and Koenig (2019), find that median and trimmed mean inflation are more closely related to slack than either headline inflation or the traditional XFE measure of core. Ball and Mazumder argue that the apparent breakdown of the Phillips curve after 2008 disappears if core inflation is measured with the weighted median.

To highlight this point, Table 1 reports estimates of a simple Phillips curve for quarterly data for 1985-2019:

(1) $$\pi_t - \pi_t^e = \alpha + \beta \tilde{u}_t + \varepsilon_t$$

where π_t denotes the annualized quarterly inflation rate; π_t^e denotes 10-year-ahead inflation expectations from the Survey of Professional Forecasters; and $\tilde{u}_t$ denotes the 4-quarter average gap between unemployment and its CBO natural rate. For both headline and XFE inflation, the fit of the equation is poor, especially when the price index is the PCE deflator, for which the adjusted *R*-squared statistics are near zero. With the median, the adjusted *R*-squared statistics are higher, and so are the estimated coefficients on the unemployment gap (–0.25 for CPI and –0.19 for PCE). These Phillips curve slope estimates are comparable with those of recent studies such as Hazell and others (2020) (–0.25 for median CPI inflation). For trimmed mean inflation, the fit and slope coefficients are in between those for median and XFE inflation.

Forecasting

By filtering out the effects of transitory shocks, a measure of core inflation should be useful for forecasting the future path of headline inflation. By this criterion, the evidence on alternative core measures is mixed. Studies such as Smith (2004) find that median inflation is more effective than XFE as a forecaster of headline inflation, but other studies such as Crone (2013) find contrary results. Verbrugge (2019) surveys the literature on core inflation and concludes that "the forecasting evidence is mixed, and relative performance depends on time period, specification, and forecast evaluation period."

More research is needed to sort out these issues. However, we will not address forecasting in this paper, because we focus on 2020-2021 and it is too early to tell which inflation measures during this period are good forecasters of future inflation. Instead, we evaluate alternative inflation measures by the other criteria—volatility and the relationship between slack and inflation—considered in past work.

All in all, our reading of the pre-pandemic evidence is that outlier-exclusion measures of core inflation have performed better than other measures. Similar evidence led the Bank of Canada to adopt a weighted median and trimmed mean as official measures of core inflation in 2016, replacing its CPIX measure, which is similar to XFE.[4] In explaining this change, Bank of Canada Deputy Governor Schembri (2017) said that "there have been large transitory shocks to CPI components not excluded from CPIX" and "this highlights an inherent weakness in measures of core inflation such as CPIX, which include a fixed and pre-determined set of components." Officials also cited evidence that the new core measures comoved more strongly with the output gap than did the CPIX (Bank of Canada, 2016).

In contrast, the Federal Reserve has maintained its focus on the traditional XFE measure of core, reporting it prominently in the Summary of Economic Projections released after FOMC meetings. We will see that the case for the Federal Reserve to move away from this practice has strengthened during 2020-2021.

III. Comparison of Fixed-Exclusion and Outlier-Exclusion Core Measures During the Pandemic

Here we compare the behavior of fixed-exclusion and outlier-exclusion measures of core inflation since the beginning of 2020. We consider core inflation in both the CPI, which traditionally has been the most prominent price index, and the PCE deflator, which the Fed has emphasized in its policymaking since the early 2000s.

We focus on two representatives of the class of outlier exclusion measures: weighted median CPI inflation and weighted median PCE inflation, which are both published by the Cleveland Fed. The weighted median is the oldest of the outlier-exclusion measures of core–the weighted median CPI was developed by Bryan and Pike (1991) and Bryan and Cecchetti (1994)–and arguably it is also the simplest. Weighted medians are calculated from inflation rates of the CPI divided into 44 categories and for the 201 categories in the PCE deflator. Later, we compare these median inflation rates to other outlier-exclusion measures, including the Dallas Fed's trimmed mean PCE inflation.[5]

We compare the weighted median CPI to two fixed-exclusion measures of core CPI inflation: XFE inflation, and the sticky-price inflation series that the Atlanta Fed produces. The Atlanta Fed variable excludes a fixed set of industries with flexible prices, defined as prices that typically adjust more often than those of the average industry in micro data. Commentators such as Krugman (2021) suggest that the Atlanta series is a good measure of core inflation.[6]

For the PCE deflator, we again compare the weighted median measure of core inflation to XFE inflation and one other fixed-exclusion variable: the COVID-insensitive inflation rate produced by the San Francisco Fed. This variable was developed in August 2020 and excludes the prices of industries that had been strongly affected by the COVID-19 crisis (see Shapiro 2020). It is natural to think that this index filters out the shocks that have caused volatility in headline inflation and therefore provides a useful measure of core inflation in the COVID-19 period.

[4] CPIX "excludes eight of the most volatile components of the CPI (fruit, vegetables, gasoline, fuel oil, natural gas, mortgage interest, intercity transportation and tobacco products) and adjusts the remainder for the effect of changes in indirect taxes" (Bank of Canada 2016).

[5] The weighted median inflation rate is constructed from the distribution of industry inflation rates, with each industry weighted as in the aggregate price index. The weighted median is the inflation rate of the industry at the 50th percentile of this distribution. For details, see the Cleveland Fed's web site.

[6] The Atlanta Fed uses the term "underlying inflation" for its sticky-price inflation rate. It does not call it core inflation. Instead, it defines "core sticky-price inflation" as the inflation rate excluding both flexible price industries and food and energy industries with sticky prices.

We first examine the paths of these different core measures over time and then examine histograms of industry price changes in several months, which help us understand why some core measures are more volatile than others.

The Paths of the Alternative Core Measures

Figure 2 shows the paths of headline inflation and the various measures of core from January 2020 through November 2021 for the CPI and October 2021 for the PCE deflator (the latest data available as this paper is completed). The graphs on the left show monthly inflation at annualized rates, and the graphs on the right show inflation over the previous 12 months. Figure 3 presents the standard deviations of the monthly rates. Several features of these data are apparent:

First, for both the CPI and the PCE deflator, the XFE measure of core inflation has been highly volatile. Its monthly standard deviation is only modestly lower than that of headline inflation (3.9 compared to 4.7 for the CPI), in contrast to the pre-COVID-19 era when its standard deviation was much lower. The series for XFE inflation follows the erratic fluctuations in headline inflation: it spikes below zero and then sharply up over April-July 2020; then spikes to high levels–around 10 percent for CPI–over April-June 2021; then plunges back down to 1 percent for CPI in August before another sharp rise in October.

The fluctuations in one-month XFE inflation have induced unusually large movements in 12-month inflation. For the CPI index, 12-month XFE inflation stayed in a narrow range from 1.6 to 2.4 percent in the pre-COVID-19 period of 2015-2019, but it fell to 1.2 in June 2020 and then rose to 5.0 in November 2021–the highest level in 30 years. The rise in 2021 led to widespread concerns about inflation, such as Summers's recent suggestion that "We're in more danger than we've been during my career of losing control of inflation in the U.S." (as reported by Miller 2021).

Second, weighted median inflation has been fairly stable over the COVID-19 era. For both CPI and PCE, the ratio of the standard deviations of median and headline inflation is less than a third and is lower than the ratio over 1985-2019. In addition, we can see in Figure 2 that median inflation has moved smoothly over time, without the transitory spikes exhibited by headline and XFE inflation. The 12-month averages of the two medians drifted down modestly over 2020 and have risen over 2021 as the economy has strengthened (a pattern we explore further below).

Turning to the fixed-exclusion measures besides XFE, we see that the behavior of the Atlanta Fed sticky-price CPI variable is in between that of XFE and weighted median. The Atlanta Fed variable follows the ups and downs in headline and XFE inflation, but in a muted way. Perhaps surprisingly, the volatility of the COVID-insensitive PCE inflation rate is similar to that of XFE inflation. The COVID-insensitive variable follows many of the fluctuations in headline and XFE inflation and has its own idiosyncratic spike in March 2021, as we discuss in what follows.

Which Industries Are Influential?

What explains the different movements of alternative core measures? The measures differ in which industries they exclude in a given month, so we can better understand them by examining inflation rates at the industry level. Here we focus primarily on measures of core CPI inflation and examine the months of April 2020 and April 2021. In April 2020, at the start of the pandemic, annualized headline CPI inflation plunged to –8.0 percent; in April 2021, it jumped to 9.6 percent as the economy recovered and hit supply constraints. In both months, alternative core inflation measures diverged sharply. Similar spikes occurred for headline PCE inflation in April 2020 and April 2021.

Figure 4 shows histograms of industry inflation rates for the CPI in the two months, with April 2020 on the left and April 2021 on the right. Each bar in the histograms has a width of 0.5 percentage points of monthly inflation (approximately 6 points of annualized inflation for low inflation rates). The height of a bar is the total weights in the CPI basket of industries with inflation rates within the range covered by the bar. For visual clarity, we truncate the vertical axis at 15 percent. For each month, the graph at the top also shows how much of the weights in each inflation range is accounted for by food or energy industries, which are excluded from XFE inflation. Similarly, the graph at the bottom shows the weights of flexible-price industries that are excluded from the Atlanta Fed's core CPI inflation measure.

The histograms show, first, that the extreme values of headline inflation arise from skewness in the distributions of inflation rates. In April 2020, a left tail of industries with large price decreases drags down headline inflation (weighted skewness = –3.8), and in April 2021 a large right tail does the opposite (weighted skewness = 4.1). The median inflation rate is not affected by this skewness and therefore is moderate in both months.

We can also see why XFE inflation is ineffective at filtering out industry shocks in the two Aprils. In both of them, the food and energy industries that are excluded are mostly near the middle of the distribution of inflation rates: changes in most food and energy prices were not especially large. Most of the industries in the tails that influence headline inflation are *not* excluded from XFE inflation. In April 2020, when XFE inflation is negative, the largest 5 annualized price falls not excluded from XFE inflation are Car and truck rental (–88.6 percent); Public transportation (–69.3 percent); Motor vehicle insurance (–59.4 percent); Lodging away from home (–58.6 percent); and Women's and girls' apparel (–48.9 percent). In April 2021, during the positive spike in XFE inflation, the largest 5 price increases not excluded from XFE inflation are a similar group: Infants' and toddlers' apparel (44.9 percent); Public transportation (97.5 percent); Lodging away from home (142.1 percent); Used cars and trucks (215.1 percent); and Car and truck rental (505.7 percent). Because the prices of food and energy items were stable compared with these outliers, the spike in XFE inflation (11.6 percent) was greater than that in headline inflation (9.6 percent).[7]

Turning to the Atlanta sticky-price measure, we can see that it also excludes many industries near the middle of the distributions in the two months. It has mixed success in excluding outliers because some of the sticky-price industries included in the measure experienced large price movements during 2020-21. For example, in April 2020 the sticky-price index excluded the XFE industry with the largest price fall, Car and truck rental, but failed to exclude the two next largest price falls among XFE industries—Public transportation and Motor vehicle insurance. The partial but not complete success in excluding outliers explains why the Atlanta Fed measure is less volatile than XFE inflation but more volatile than the weighted median.

The other fixed-industry exclusion measure examined above, COVID-insensitive inflation, is measured only for PCE inflation. Like the Atlanta Fed core measure, it filters out some but not all of the largest price changes in April 2020 and April 2021. The potential for instability in the COVID-insensitive index is illustrated most clearly by March 2021, when it spiked to 7.9 percent. For that month, Figure 5 presents a histogram of PCE industry price changes, which reveals that an important outlier not excluded from the COVID-insensitive index was Financial service charges, fees, and commissions with an annualized rise of 95.7 percent. The effect of such an outlier is magnified by the fact that the COVID-

[7] PCE XFE inflation in April 2020 and April 2021 was affected by price movements in similar industries to those that affected the CPI XFE. In April 2020, the largest 5 annualized price falls among industries not excluded from PCE XFE inflation were Motor vehicle rental (–88.2 percent); Used autos (–78.3 percent); Air transportation (–78.3 percent); Hotels and motels (–58.1 percent); and Financial service charges, fees, and commissions (–57.8 percent). In April 2021, the largest 5 annualized price increases among industries not excluded from PCE XFE inflation were Air transportation (189.5 percent); Used light trucks (206.8 percent); Used autos (216.6 percent); Spectator sports (216.7 percent); and Motor vehicle rental (505.6 percent); they are followed by Hotels and motels (174.7 percent).

insensitive index excludes more than 60 percent of the weighted industries in the PCE basket. The small size of the remaining basket makes the index more responsive to large price changes for the included items.

IV. Core Inflation Measures and Economic Slack

The noise in headline inflation arising from industry price changes can obscure the Phillips curve relationship between inflation and economic slack. Because it filters out this noise, a good core inflation measure should have a stronger relationship to slack, and pre-pandemic research judged core measures partly by that criterion. Here we examine some simple evidence on the comovement of slack with alternative core measures over 2020-2021. Once again, the starkly different movements in the core series mean the data for this episode are informative.

In addition to the core inflation measures that we analyze above, we consider two other variables that are meant to capture the part of inflation that is correlated with slack. One, the San Francisco Fed's measure of cyclical PCE inflation, excludes industries with prices that typically do not comove with slack (for details, see Mahedy and Shapiro 2017). The other, Stock and Watson's (2019) cyclically-sensitive PCE inflation, is similar but gives weights to industries between zero and one, according to their covariation with real activity, rather than fully including or fully excluding each industry. The San Francisco Fed staff and Stock and Watson do not use the term "core inflation" for their variables, but the measures are interesting here because they are designed to have one of the properties of a good core measure.

As a simple measure of slack, we again use the gap between unemployment and its natural rate as measured by the Congressional Budget Office (CBO).[8] We examine the relationship between the level of core inflation over the last 12 months and the average unemployment gap over the same 12 months.

Figures 6 and 7 present the results for various core inflation measures for the CPI and PCE, respectively. Each graph shows the path over time of a core measure and the unemployment gap. The Phillips curve implies that these variables should comove negatively, with core inflation falling as the unemployment gap rises.

Once again, for both price indexes the results for XFE inflation are negative: the data are not consistent with a stable Phillips curve. XFE inflation and slack sometimes move in the same rather than opposite directions, notably over April-September 2020 for the PCE deflator. Starting in April 2021, XFE inflation is consistently much higher than it was in earlier parts of the pandemic despite a similar range of unemployment gaps.

Again echoing our earlier results, median inflation performs better: we can see a negative relationship between median inflation and the unemployment gap. For both the CPI and the PCE deflator, the 12-month median drifts down from January 2020 through February 2021 as the 12-month unemployment gap rises, and after that the median rises as unemployment falls. The slope of the unemployment-inflation tradeoff seems fairly stable over most of the COVID-19 period, specifically from January 2020 through August 2021. A caveat is that the relationship seems to change in the three most recent months, September-November 2021, when inflation rises faster than one would expect based on the unemployment gap. Future research should explore this anomaly. (One possible explanation is that the unemployment gap does not accurately capture the tightness of the labor market, which has been greater by other measures such as the job openings rate.)

[8] This gap moves closely with the output gap estimated by the CBO, because the CBO imposes Okun's Law in estimating the two gaps. The advantage of examining unemployment is that it is available at the monthly frequency and output is not. At the same time, with the unprecedented nature of the COVID-19 crisis, ascertaining the natural rate of unemployment and the resulting unemployment gap is especially difficult.

The performances of the Atlanta sticky-price and San Francisco COVID-insensitive measures of core are once again middling. These variables appear to have a negative relationship with slack, but it is less tight than it is for median inflation. The same is true for the San Francisco measure of cyclical PCE inflation. The Stock-Watson measure of cyclical inflation performs less well: in rises in the early part of the pandemic despite growing slack, and the anomalous increase in inflation at the end of the sample is pronounced.

V. Alternative Outlier-Exclusion Measures

So far we have shown that one simple outlier-exclusion measure of core inflation, the weighted median, has been more stable and more closely related to economic slack over 2020-2021 than several fixed-exclusion measures. Here, we compare the weighted median to other members of the outlier-exclusion class of core measures, specifically, various trimmed means of industry inflation rates. The median is a limiting case of this class in which 50 percent of the distribution of inflation rates is trimmed from each side of the median.

We first examine the two trimmed-mean measures of core inflation published by Federal Reserve Banks, the Dallas Fed trimmed PCE inflation and the Cleveland Fed trimmed CPI inflation. The Dallas Fed measure removes industries with total weights of 31 percent from the top of the distribution of PCE industry inflation rates and industries with total weights of 24 percent from the bottom; the asymmetry in trimming is meant to produce an average level of core inflation that matches headline inflation. The Cleveland Fed variable symmetrically trims 8 percent of the weights from both the top and the bottom of the CPI industry inflation rates.

Figure 8 shows the paths over 2020-2021 of one-month and 12-month core inflation as measured by the Dallas and Cleveland Fed trimmed means and compares them to their respective weighted median inflation rates. Figure 9 shows the standard deviations of each one-month and 12-month series. We see that the trimmed means, like the weighted medians, filter out most of the monthly fluctuations in headline inflation and are more stable than fixed-exclusion core measures. There are some nuances to the results, however, which differ for the PCE and CPI price indexes.

For the PCE, we can see first from the 12-month series that the trimmed mean is somewhat below the median throughout the 2020-2021 period. The difference averages 0.40 percentage points and is fairly stable over the period. This finding is not surprising: it reflects the asymmetric trimming by the Dallas Fed, which reduces the trimmed mean. We also see that the standard deviation of the trimmed mean is modestly below that of the median (0.95 vs. 1.10).

For the CPI, the trimmed mean is not systematically higher or lower than the median, but it is substantially more volatile: the standard deviation is 2.10 percentage points compared to 1.51 for the median. This difference reflects the fact that the trimmed mean follows headline inflation somewhat more than the median does when headline spikes down in April 2020 and up in June 2020, April-June 2021, and October 2021.

The industry-level data reveal that volatility in the trimmed mean CPI occurs because the Cleveland Fed's 8 percent trims from the top and bottom are too narrow to exclude all the industries with large price changes. For example, in April 2021, when headline CPI inflation spiked to 9.6 percent at a monthly annualized rate, the Cleveland Fed trimmed mean failed to exclude industries such as Processed fruits and vegetables; Recreation; and Household furnishings and operations, with annualized price increases of 15.8 percent, 11.6 percent, and 11.1 percent, respectively. Consequently, trimmed mean inflation reached an annualized 4.5 percent. Median CPI inflation was 2.9 percent.

Motivated by these results, we further investigate the effects of alternative amounts of trimming. We construct trimmed means for the CPI and PCE with symmetric trimming rates from 0 percent (as in the case of headline inflation) to 50 percent on each side (as in the case of median). Figure 10 plots the standard deviation of the monthly annualized inflation rate over 2020-2021 for the various trimmed means against the total trimming applied. For both the CPI and the PCE deflator, we see that the volatility of the trimmed mean falls as the amount of trimming rises from zero to about 25-30 percent on each side of the distribution, or 50-60 percent in total. Beyond that point, there is little effect of additional trimming. These findings confirm that the Cleveland Fed's trim, which totals 16 percent, is not optimal for reducing volatility while the Dallas Fed's trim, which totals 55 percent, has similar volatility to the weighted median.

Figure 10 also compares the Dallas trim to a symmetric trim for PCE with the same 55 percent total (27.5 percent on each side). We see that the choice of symmetry or asymmetry, while affecting the average level of the trimmed mean, has essentially no effect on volatility for a given total amount of trimming.

In sum, we find that the choice between a median measure of core inflation and a heavily trimmed mean such as the Dallas Fed's does not matter materially for volatility over the pandemic era. We also find (in results not shown) that this choice does not matter for the comovement between the core inflation measure and the unemployment gap. In contrast, a light trim such as Cleveland's produces a core measure that is more volatile and less closely related to slack.

VI. Conclusion

How should economists and policymakers measure core inflation? Since the 1970s, the primary measure of core at the Federal Reserve has been the inflation rate excluding food and energy (XFE inflation). Yet, even before the COVID-19 pandemic, there was substantial evidence that outlier-exclusion measures of core—weighted medians and trimmed means—were better by criteria including volatility and relation to economic slack. Such evidence led the Bank of Canada to adopt this kind of core measure in 2016, replacing its XFE-type measure.

The last two years have been highly informative about the behavior of alternative core measures. Headline inflation has fluctuated erratically as a result of sectoral shocks related to the pandemic, and core measures have had varying success in filtering out these shocks. XFE inflation has performed quite poorly by the criteria of volatility and relation to slack. Fixed-exclusion measures of core that exclude a wider set of industries, such as the Atlanta Fed's sticky-price inflation rate, have performed better, but the most successful measures have been weighted medians and trimmed means. This experience has strengthened the case for the Federal Reserve to revise its measurement of core inflation.

The success of outlier-exclusion measures of core is impressive when we consider some of the measures they outperform. They are less variable during the COVID-19 period than even the COVID-19-insensitive inflation rate designed specifically to filter out the effects of the pandemic. They are more closely related to slack than cyclically-sensitive inflation rates designed to maximize correlation with slack.

Recent experience also provides evidence on the relative performance of core measures that trim different amounts of the industry price-change distribution. For the pandemic period, it appears best to trim at least 25-30 percent from each side of the distribution. It does not matter much whether the trimming is increased from that level to the 50 percent that defines the median. Future research should examine whether these results hold over longer time periods.

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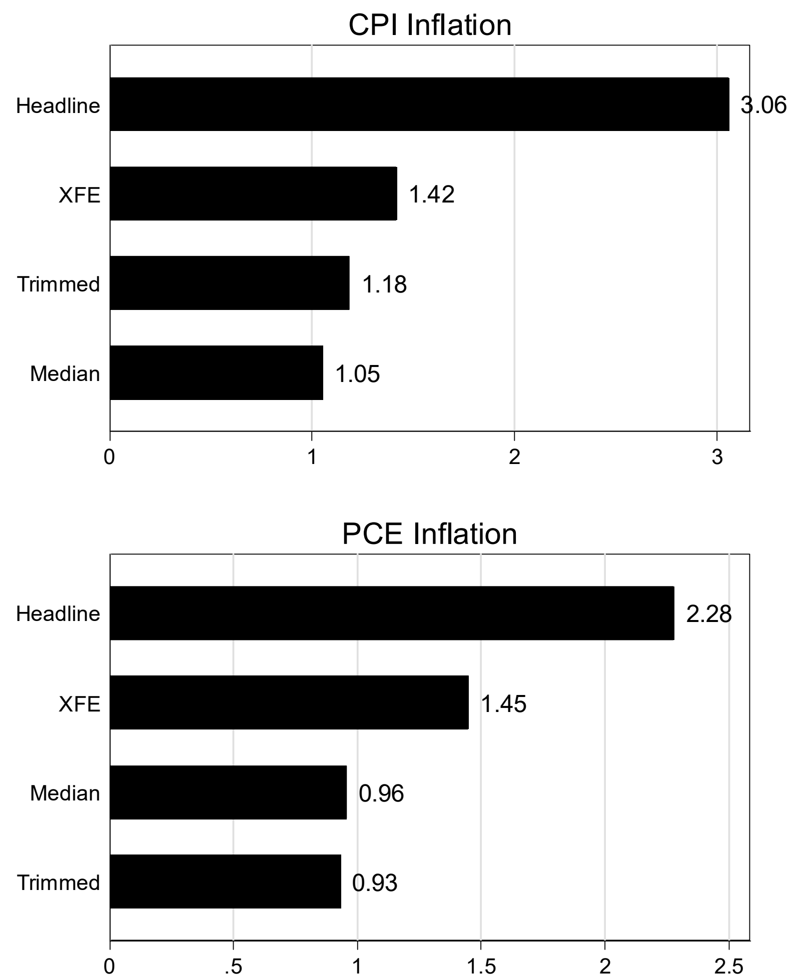
Table 1. Phillips Curve Estimates for Selected Inflation Measures, 1985–2019

	R-squared	β	(s.e.)	α	(s.e.)	*N*
CPI Inflation						
Headline	0.014	-0.174**	(0.087)	-0.154	(0.160)	140
XFE	0.161	-0.170***	(0.035)	-0.118**	(0.053)	140
Trimmed	0.186	-0.183***	(0.039)	-0.153***	(0.051)	140
Median	0.376	-0.254***	(0.036)	0.130***	(0.043)	140
PCE Inflation						
Headline	-0.002	-0.068	(0.066)	-0.410***	(0.124)	140
XFE	0.010	-0.054*	(0.031)	-0.411***	(0.059)	140
Trimmed	0.206	-0.149***	(0.025)	-0.210***	(0.041)	140
Median	0.279	-0.190***	(0.025)	0.204***	(0.041)	140

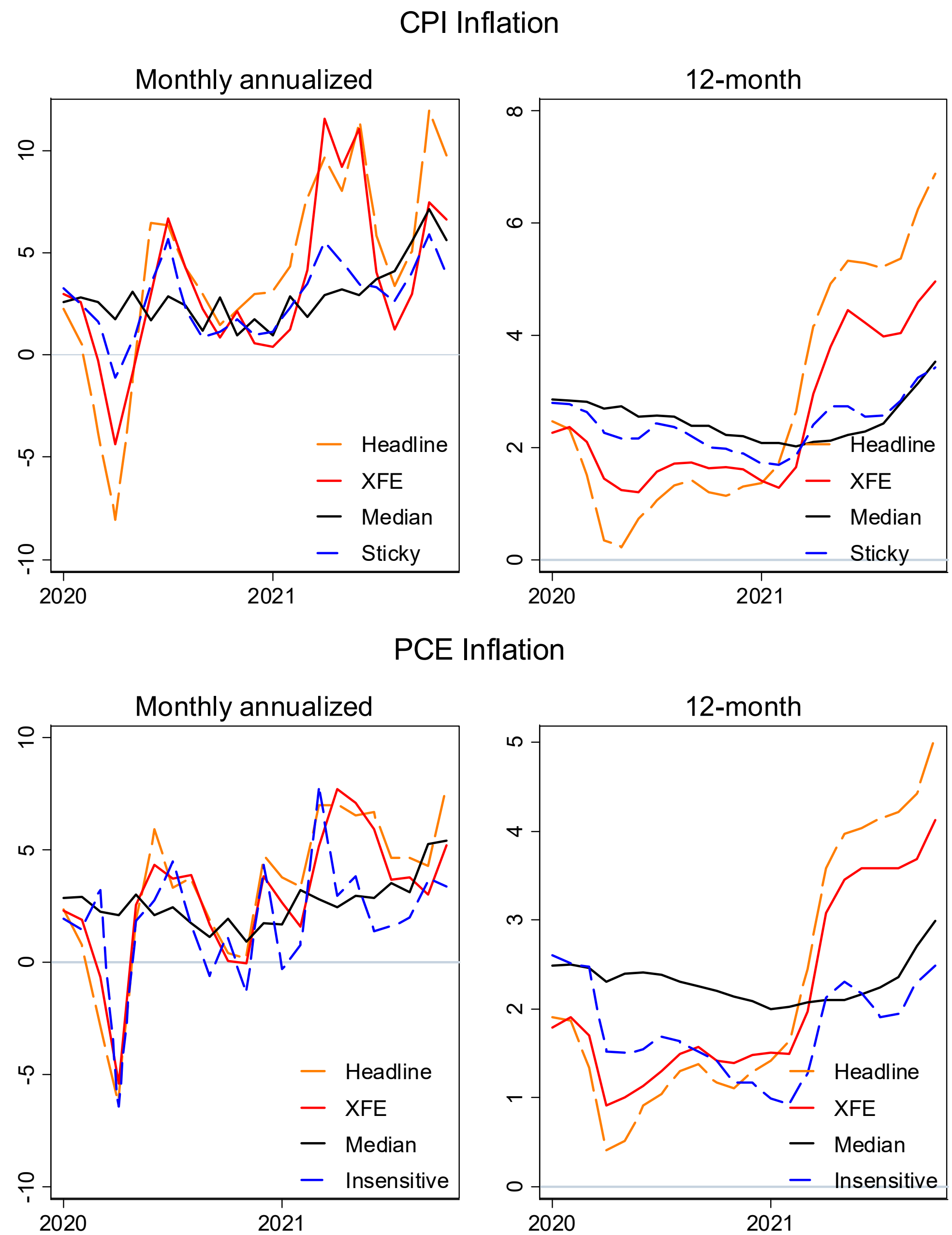
Note: "XFE" denotes inflation measure excluding food and energy. "Median" denotes weighted median series produced by the Federal Reserve Bank of Cleveland staff. "Trimmed" denotes the trimmed mean series prepared by the Federal Reserve Bank of Cleveland staff and Federal Reserve Bank of Dallas staff for the CPI and PCE, respectively. Equation estimated: $\pi_t - \pi_t^e = \alpha + \beta\tilde{u}_t + \varepsilon_t$ where π_t = quarterly seasonally adjusted annualized inflation; π_t^e = 10-year-ahead Survey of Professional Forecasters inflation expectations; and $\tilde{u}_t$ = trailing 4-quarter average gap between unemployment and its CBO natural rate. Table reports adjusted *R*-squared statistics; point estimates; robust standard errors (s.e.) in parentheses; and number of observations (*N*). *, **, and *** denote statistical significance at the 10, 5, and 1 percent level, respectively.

Figure 1. Pre-pandemic Volatility of Monthly Annualized Inflation, 1985–2019
(Standard deviation; percentage points)



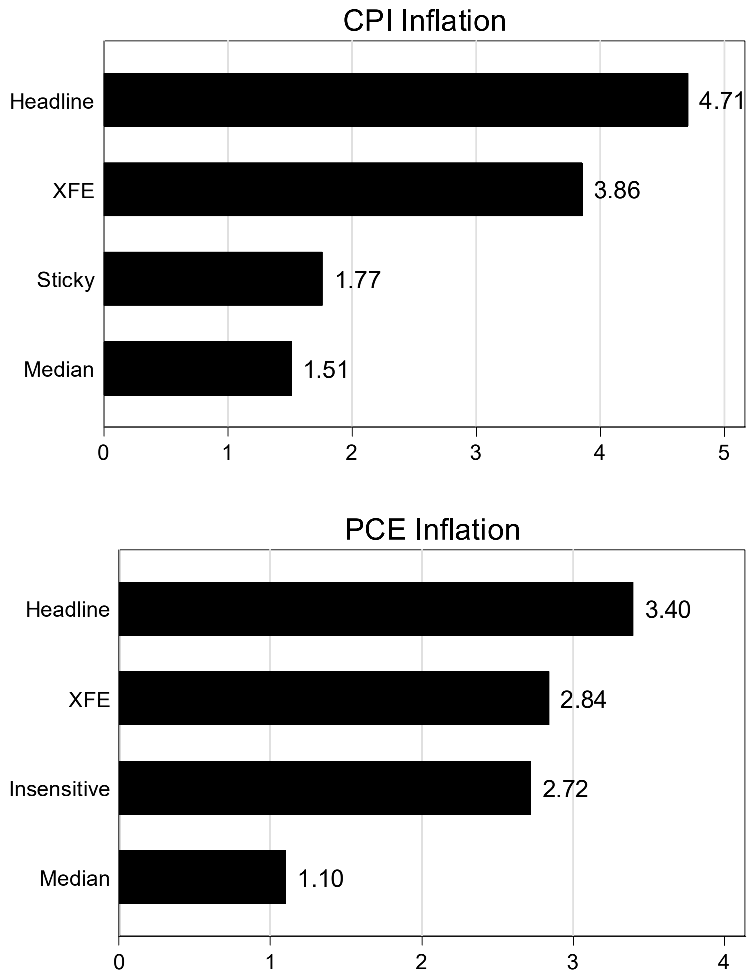
Note*:* “XFE” denotes inflation measure excluding food and energy. “Median” denotes weighted median series produced by the Federal Reserve Bank of Cleveland staff. “Trimmed” denotes the trimmed mean series prepared by the Federal Reserve Bank of Cleveland staff and Federal Reserve Bank of Dallas staff for the CPI and PCE, respectively.

Figure 2. Inflation Since COVID-19, 2020–2021 (percent)



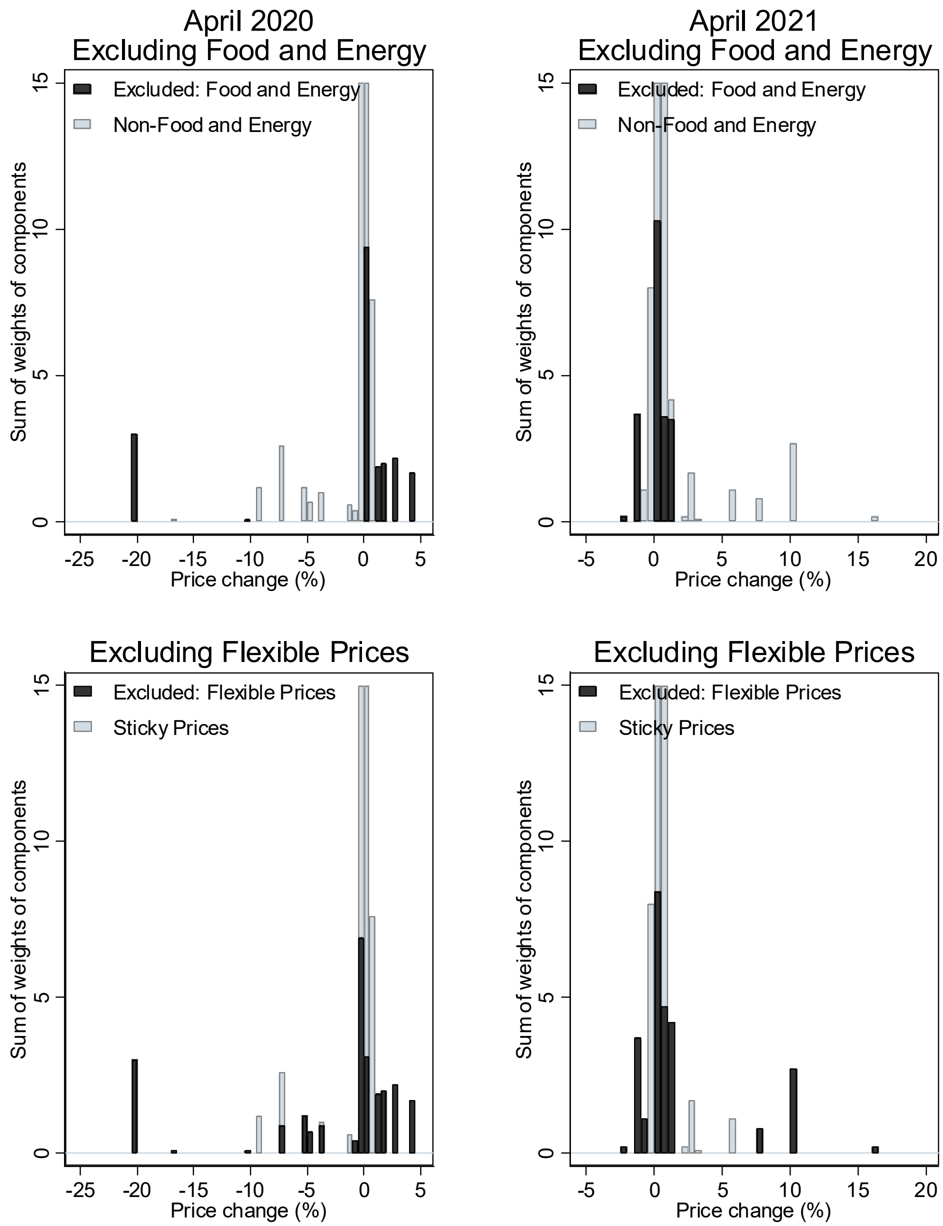
Note*:* “XFE” denotes inflation measure excluding food and energy. “Median” denotes weighted median series produced by the Federal Reserve Bank of Cleveland staff. “Insensitive” denotes series produced by Federal Reserve Bank of San Francisco staff (Shapiro 2020) that excludes food and energy as well as additional PCE components for which either prices or quantities moved in a statistically significant manner at the onset of the COVID-19 pandemic, between February and April 2020. “Sticky” denotes series produced by the Federal Reserve Bank of Atlanta staff based on a subset of CPI components assessed as slow to change due to the low frequency of price adjustment.

Figure 3. Volatility of Monthly Annualized Inflation During 2020–21
(Standard deviation; percentage points)



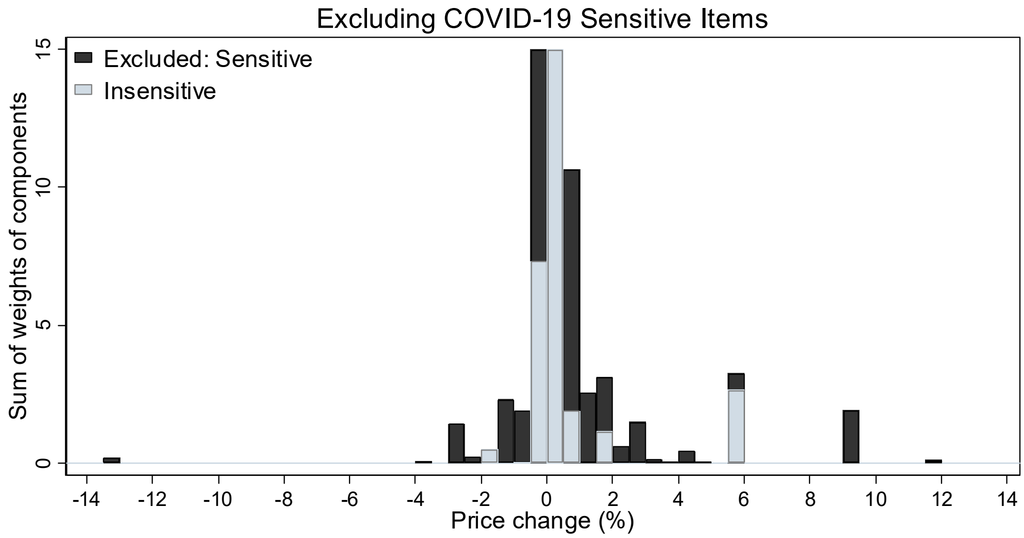
Note*:* "XFE" denotes inflation measure excluding food and energy. "Median" denotes weighted median series produced by the Federal Reserve Bank of Cleveland staff. "Insensitive" denotes series produced by Federal Reserve Bank of San Francisco staff (Shapiro 2020) that excludes food and energy as well as additional PCE components for which either prices or quantities moved in a statistically significant manner at the onset of the COVID-19 pandemic, between February and April 2020. "Sticky" denotes series produced by the Federal Reserve Bank of Atlanta staff based on a subset of CPI components assessed as slow to change due to the low frequency of price adjustment.

Figure 4. April 2020 and April 2021: Histogram of Changes in the Prices of CPI Categories
(Monthly, not annualized, percent)



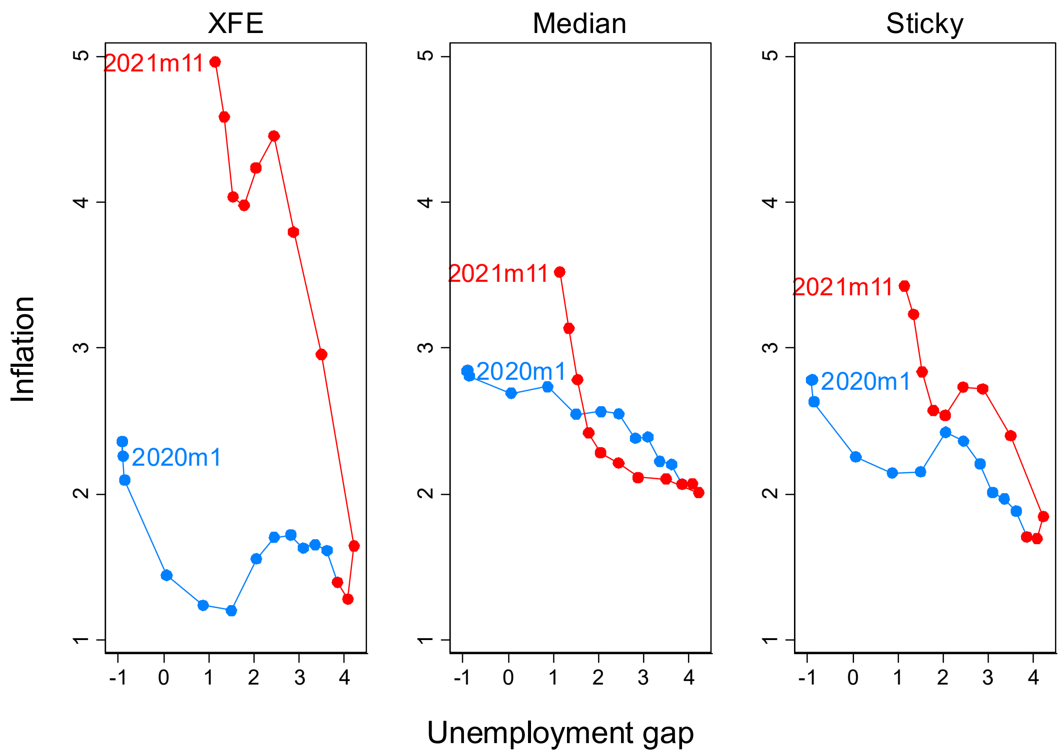
Note: Figure reports non-annualized inflation rates. Vertical axis cut off at 15. Weights computed following Dolmas (2005).

Figure 5. March 2021: Histogram of Changes in the Prices of PCE Categories
(Monthly, not annualized, percent)



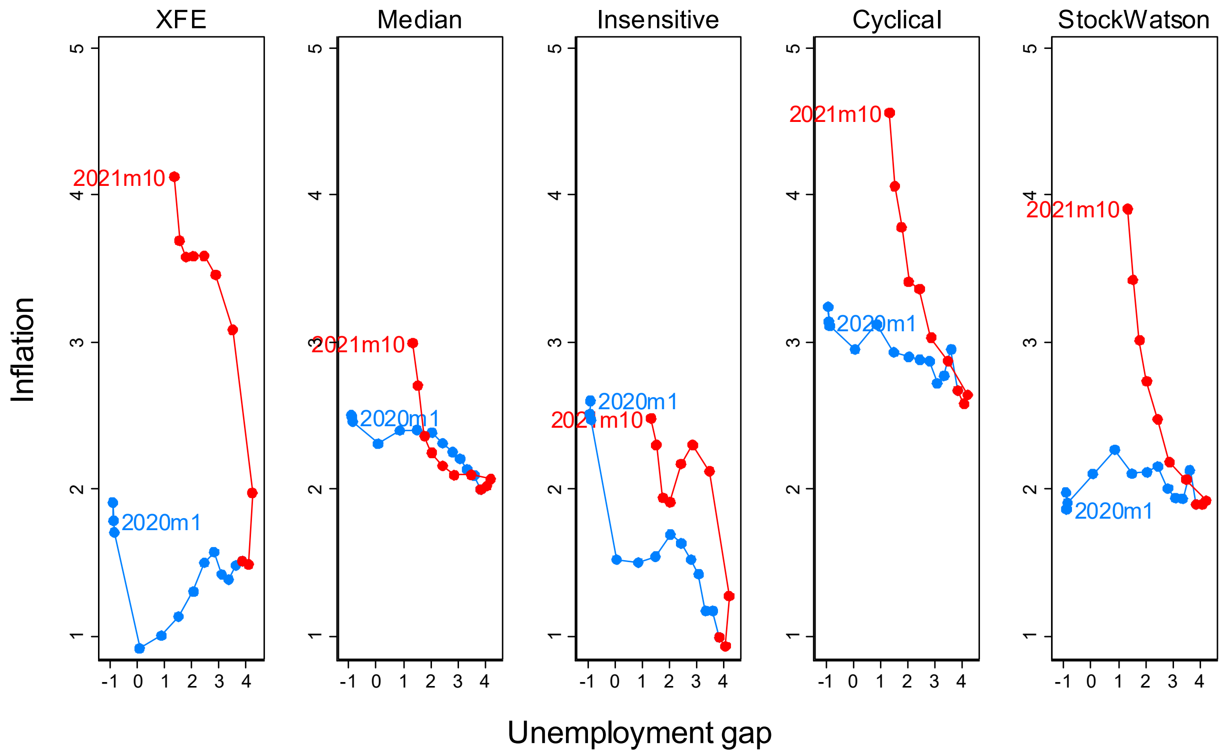
Note: Figure reports non-annualized inflation rates. Vertical axis cut off at 15. Weights computed following Dolmas (2005).

Figure 6. CPI Inflation: Relation with Unemployment Gap, 2020–2021
(12-month rates)



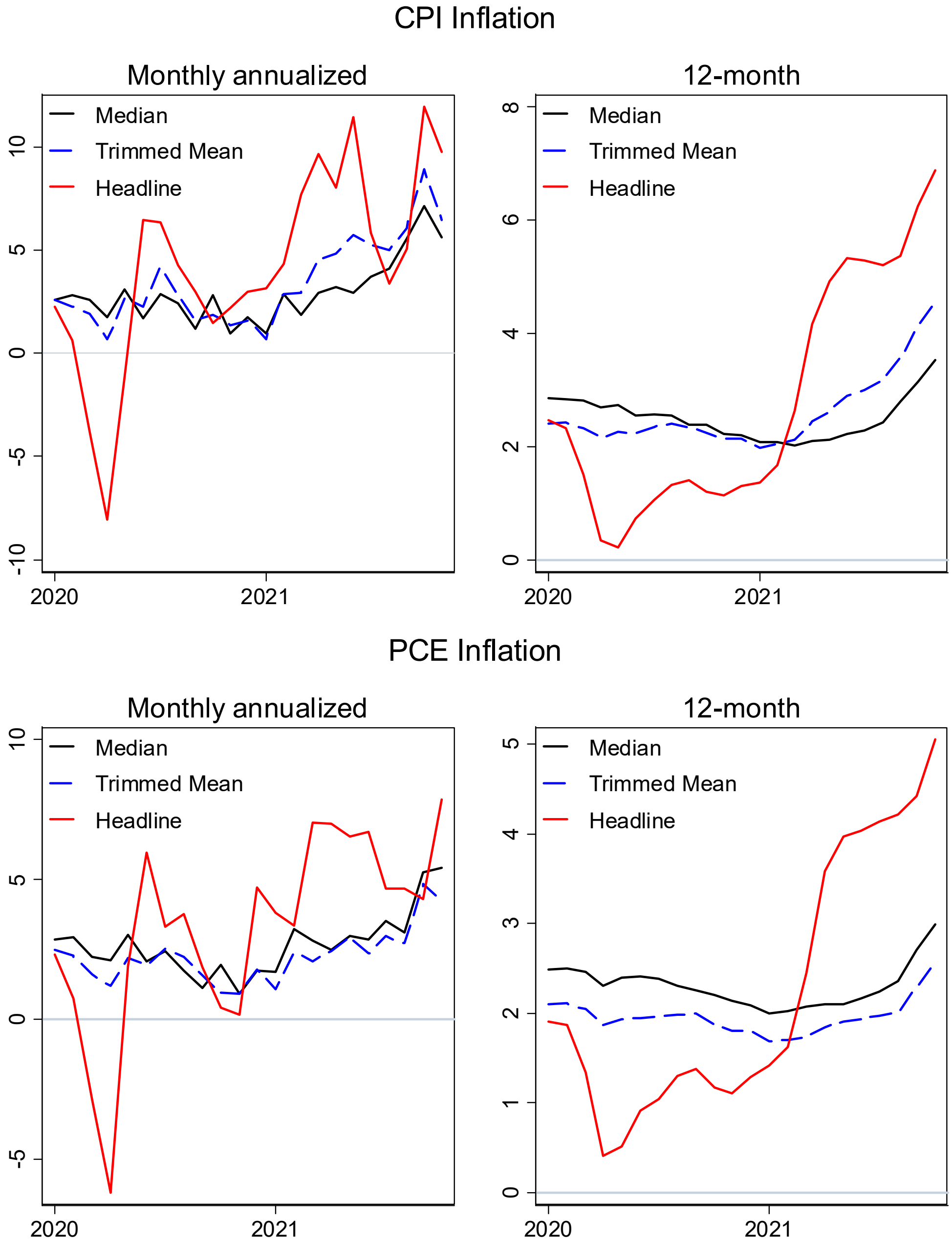
Note: Blue points indicate 2020. Red dots indicate 2021. Unemployment gap indicates 12-month average of unemployment rate minus Congressional Budget Office (CBO) estimate of natural rate. Note*:* "XFE" denotes inflation measure excluding food and energy. "Median" denotes weighted median series produced by the Federal Reserve Bank of Cleveland staff. "Sticky" denotes series produced by the Federal Reserve Bank of Atlanta staff based on a subset of CPI components assessed as slow to change due to the low frequency of price adjustment.

Figure 7. PCE Inflation: Relation with Unemployment Gap, 2020–2021
(12-month rates)



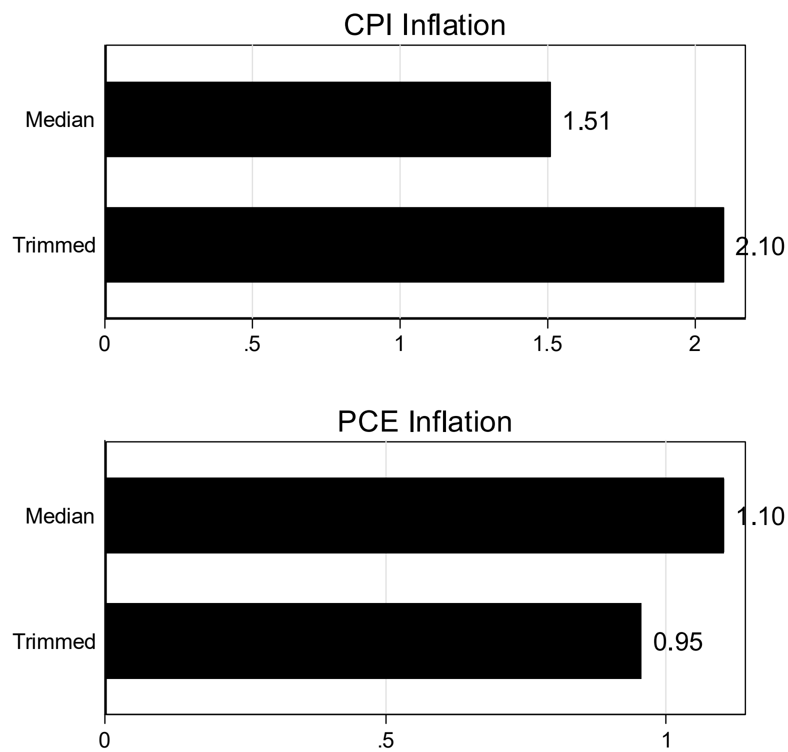
Note: Blue points indicate 2020. Red dots indicate 2021. Unemployment gap indicates 12-month average of unemployment rate minus Congressional Budget Office (CBO) estimate of natural rate. "XFE" denotes inflation measure excluding food and energy. "Median" denotes weighted median series produced by the Federal Reserve Bank of Cleveland staff. "Insensitive" denotes series produced by Federal Reserve Bank of San Francisco staff (Shapiro 2020) that excludes food and energy as well as additional PCE components for which either prices or quantities moved in a statistically significant manner at the onset of the COVID-19 pandemic, between February and April 2020. "Cyclical" denotes measure produced by Federal Reserve Bank of San Francisco staff (Mahedy and Shapiro 2017) that excludes food and energy and also excludes additional items assessed as being acyclical. "StockWatson" denotes cyclically sensitive inflation measure of Stock and Watson (2019) published on Federal Reserve Bank of Atlanta Underlying Inflation Dashboard.

Figure 8. Median and Trimmed-Mean Inflation, 2020–2021
(percent)



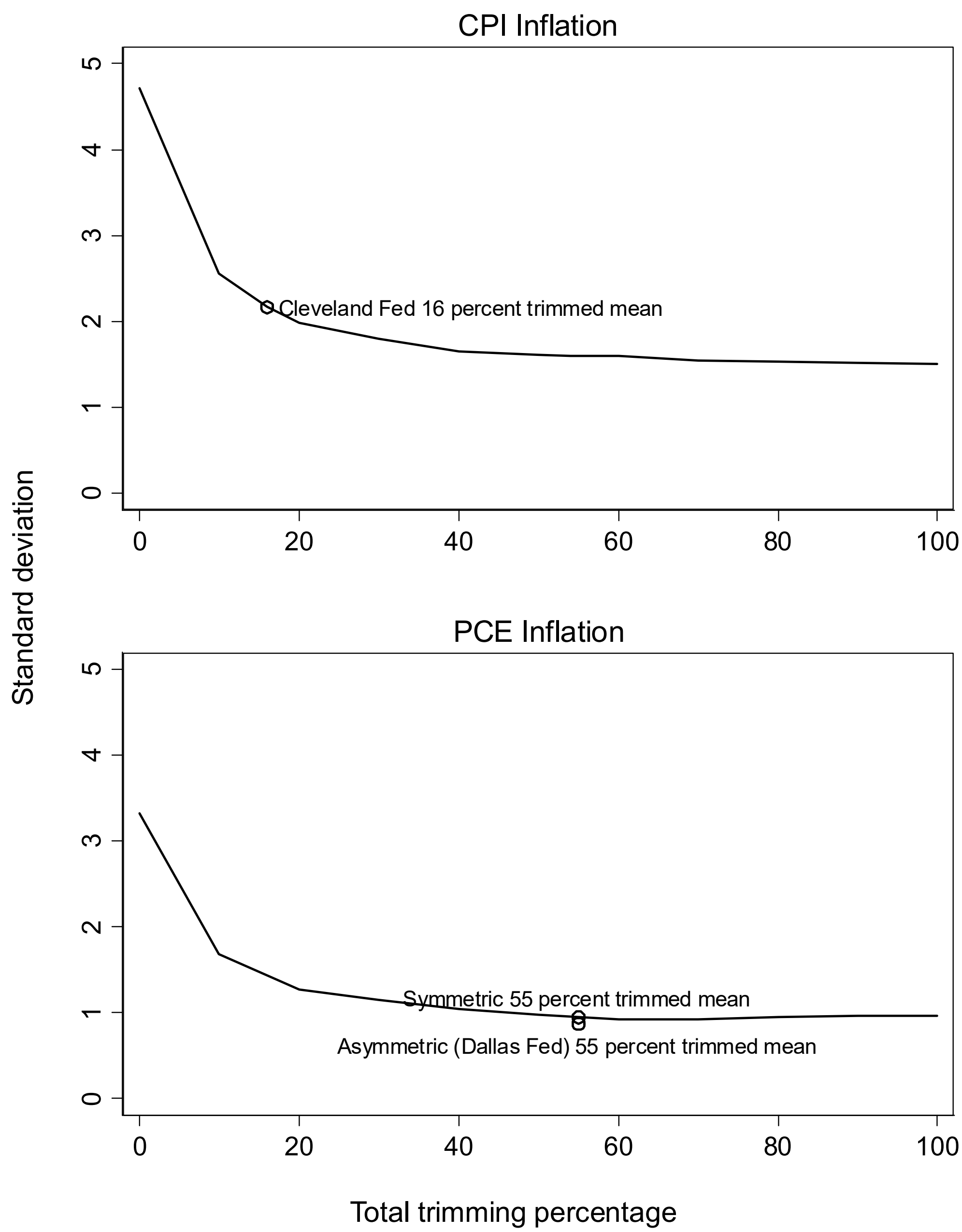
Note*:* “Median” denotes weighted median series produced by the Federal Reserve Bank of Cleveland staff. “Trimmed” denotes the trimmed mean series prepared by the Federal Reserve Bank of Cleveland staff and Federal Reserve Bank of Dallas staff for the CPI and PCE, respectively.

Figure 9. Volatility of Median and Trimmed-Mean Monthly Annualized Inflation During 2020–2021
(Standard deviation; percentage points)



Note*:* "Median" denotes weighted median series produced by the Federal Reserve Bank of Cleveland staff. "Trimmed" denotes the trimmed mean series prepared by the Federal Reserve Bank of Cleveland staff and Federal Reserve Bank of Dallas staff for the CPI and PCE, respectively.

Figure 10. Trimmed-Mean Inflation Volatility vs. Total Trimming Percentage, 2020–2021
(Standard deviation of monthly annualized inflation; percentage points)



Note: Total trimming percentage indicates sum of the proportion of price changes trimmed from upper and from lower end of the weighted distribution of monthly price changes.

PUBLICATIONS

Measuring Core Inflation: The Stress Test of COVID-19

Working Paper No. **WP/21/291**