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The Nonpuzzling Behavior of Median Inflation

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1 Introduction

For decades, textbooks have explained inflation behavior with Friedman's (1968) Phillips curve: the inflation rate depends on expected inflation and the deviation of unemployment from its natural rate. Yet this theory has always been controversial, and skepticism has been rampant in the decade since the 2008 financial crisis. For several years following the crisis, researchers such as Stock (2011) and Coibion and Gorodnichenko (2015) puzzled over a "missing deflation": inflation did not fall much despite a sharp rise in the unemployment rate. More recently, as the economy has approached full employment, economists have puzzled over the failure of inflation to rise toward the Federal Reserve's target of 2%. According to Bernstein (2017), recent low inflation is "puzzle #1 in economics."

Some observers, such as The Economist (2017) and Summers (2017), have lost patience with the Phillips curve and suggested it is "broken." Blinder (2018) wonders "whether the Phillips curve has died or has just taken an extended vacation." Blanchard (2016) offers a tepid defense of the theory, saying the Phillips curve is alive and "at least as well as it has been in the past." Blanchard emphasizes that the residuals in the relationship are large.

This paper argues that inflation behavior is less puzzling if we separate the headline inflation rate into two components: an underlying or core level of inflation that the Phillips curve explains, and a transitory component arising from changes in relative prices due to microeconomic factors. A good proxy for the core inflation rate is the weighted median of price changes across industries.

Many economists, and the policymakers at the Federal Reserve, also examine core inflation in an effort to filter out transitory shocks. However, the usual measure of core inflation is the inflation rate excluding the prices of food and energy. That variable filters out shocks in the food and energy industries, but many other industries also experience large price changes that materially influence the headline inflation rate. The weighted median filters out all these shocks, producing a less noisy measure of core inflation, one with movements that are easier to understand.

Section 2 of this paper briefly reviews the theoretical case for measuring core inflation with the weighted median, and the previous empirical literature. Section 3 begins our empirical work by examining the univariate behavior of alternative measures of core inflation. We show that, for both the CPI and PCE deflator measures of inflation, the weighted median of industry price changes is a less volatile measure of core inflation than inflation excluding food and energy.

Section 4 illustrates the usefulness of the weighted median inflation rate with a careful study of inflation over 2017 and early 2018. Some observers believe that inflation behavior has been especially puzzling during this period; in particular, despite low unemployment rates, the Fed's preferred measure of core inflation, the twelve-month percentage change in the PCE deflator less food and energy, fell from 1.9 in December 2016 to 1.3 in September 2017 and 1.5 in December. In a September speech, Fed Chair Yellen said that low inflation before 2017 was consistent with the Fed's specification of the Phillips curve, but:

> This year, the shortfall of inflation from 2 percent... is more of a mystery, and I will not say that the [Federal Open Market] Committee clearly understands what the causes are of that.

We show that this mystery disappears when the weighted median rather than inflation ex-food and energy is used as a measure of core inflation. The weighted median filters out large price decreases in a number of industries that pushed down the Fed's core-inflation measure during 2017. Measuring core inflation with the weighted median also helps resolve confusion among policymakers about an apparent uptick in inflation in early 2018.

Section 5 turns to the Phillips curve. We examine the fit of a simple specification in which inflation depends on expected inflation (as measured by long-term forecasts from the Survey of Professional Forecasters) and the cyclical component of unemployment (deviations from a trend estimated with the Hodrick-Prescott filter). We first measure core inflation with inflation less food and energy, and see the source of recent skepticism about the Phillips curve: the equation fits the data poorly, especially when inflation is measured with the PCE deflator, and especially since 2008. We then see that the Phillips curve shows up clearly when core inflation is measured more accurately with median inflation.

All in all, our results suggest that economists should use the weighted median or related variables (such as trimmed means of industry price changes) as their primary measures of core inflation. Researchers should also work on refining these measures. Section 6 concludes this paper by discussing directions for future research.

2 Background

In explaining fluctuations in inflation, economists often suggest that changes in prices in certain industries have pulled the aggregate inflation rate up or down. We will see examples from 2017 and 2018. This practice can be dangerous, because there are always some prices that rise by significantly more than aggregate inflation and others that rise by less or fall; that is, there are always fluctuations in relative prices. If the inflation rate is higher than a theory predicts, one can always find a cheap "explanation" by citing industries whose prices have risen by more than average; low inflation can be handled by citing industries with price decreases.

Ball and Mankiw (1995) suggest a more disciplined way of determining whether relative price changes have influenced inflation. They present a theory in which relative price changes matter if they are unusually large, which implies that the inflation rate is influenced by asymmetries in the distribution of price changes across industries. If there is a tail of unusually large price increases, skewing the distribution to the right, that raises inflation; a tail of unusually large price decreases does the opposite. This result arises in Ball and Mankiw's model because it is costly for firms to adjust their nominal prices. With costly adjustment, large shocks to industries' optimal prices have disproportionately large effects on actual price changes because they trigger adjustments while prices in other industries are sticky. Empirically, Ball and Mankiw show that aggregate inflation in the U.S. is affected strongly by asymmetries in the price-change distribution.

Measures of core inflation are intended to filter out the effects on headline inflation of unusual relative price changes. In their pioneering work on core inflation, Bryan and Cecchetti (1994) extend the reasoning of Ball and Mankiw. If asymmetries in the price-change distribution cause fluctuations in headline inflation, then one can measure core inflation by eliminating the effects of these asymmetries. A simple variable that does so is the median of industry price changes, weighted by industries' relative importance in the aggregate price index.

We can think of the weighted median as generalizing the idea behind the traditional measure of core inflation, the inflation rate excluding food and energy. Many of the large relative price changes that influence inflation occur in food and energy industries, so dropping those industries helps to isolate the trend underlying the noisy data for headline inflation. However, large relative price changes often occur in other industries. Based on the disaggregated PCE deflator, Dolmas (2005) reports that large price changes are common in many industries; examples include computers and software, televisions, clothing, airline services, fees for financial services, and auto insurance premiums. As we will see in our empirical work, filtering out large shocks to all industries produces core-inflation measures that are less volatile and easier to understand than inflation excluding food and energy.

Weighted-median measures of core inflation, as well as trimmed means of industry price changes–an alternative way to filter out large relative price changes–have gained increasing attention in recent years. In 2016, the Bank of Canada announced it would use a weighted median and trimmed mean as its primary measures of core inflation. Yet most research on the behavior of core inflation still focuses on inflation excluding food and energy, and the Fed's preferred measure of core inflation is based on the PCE deflator excluding food and energy. Fed staff produce forecasts of this core measure as well as headline inflation, and it is the focus of much discussion in FOMC meetings and speeches by Fed officials. We hope that this paper helps push economists and policymakers toward changing their measures of core inflation.[1]

We examine the monthly and quarterly behavior of two versions of weighted median inflation. One is the weighted median CPI inflation rate that the Cleveland Fed has produced since 1967, which is currently based on dividing the basket of goods in the CPI into 45 industries. The other is a weighted median PCE deflator that we have constructed from data on 178 components of the deflator provided by the Dallas Fed. Researchers at Dallas use these data to construct a trimmed-mean measure of core inflation; we construct a weighted median instead for comparability with the median CPI series. The relative merits of the weighted-median and trimmed-mean measures of core inflation are an important topic for future research.[2]

[1]Several researchers have found evidence in favor of using weighted median and trimmed mean inflation to measure core inflation. Bryan and Cecchetti (1994) find that the weighted median CPI inflation rate best predicts headline inflation, even over and above past headline CPI inflation rates themselves. They also report lower standard deviations of median and trimmed mean inflation than the standard deviations of CPI and CPIX inflation between 1967 and 1992. Similarly, Bryan et al. (1997) find that trimmed mean inflation measures are consistently the most efficient estimators of core inflation when examining a 36-month centered moving average of actual inflation. Smith (2004) presents evidence in favor of median inflation, where she tests which core inflation measures best forecast 12-month ahead inflation. Ball and Mazumder (2011) find median inflation to be superior to CPIX over 1983-2010 when one applies the Stock and Watson (2007) procedure of decomposing inflation into its permanent and transitory components. In his comparison of alternative core inflation measures, Clark (2001) presents evidence that trimmed mean measures are best at tracking trend inflation, at both the monthly and quarterly frequency. Brischetto and Richards (2006) also advocate using trimmed mean measures of core inflation, where their evidence suggests that trimmed measures have the highest signal-to-noise ratios. The weight of evidence even goes beyond scholarly work. For instance, the Bank of Canada ceased using CPIX to measure core inflation in January 2017, and instead switched to using weighted median and trimmed mean inflation (as well as the common component of CPI inflation. See Bank of Canada, 2016).

On the other hand, there are some authors who present less favorable evidence in favor of using median and trimmed mean measures of core inflation. For example, Crone et al. (2013) argue that core inflation– including weighted median and trimmed mean CPI inflation–is not necessarily the best predictor of headline inflation, and that results are sensitive to the inflation measure and time horizon examined. More recently, Gamber and Smith (2016) exploit the time-series properties of the components of disaggregated PCE data to re-weight the PCE measure of inflation, where their re-weighted measure of inflation produces superior 12-month ahead forecasts to alternatives such as median and trimmed mean inflation.

[2]We compute weighted median inflation by using the monthly series reported by the Cleveland Fed. We convert these monthly median inflation rates to monthly price levels, which are then averaged over three months to get quarterly price levels. Quarterly median inflation is then the annualized percentage change in the quarterly price level.

3 Univariate Evidence

This section examines the univariate behavior of headline inflation; inflation excluding food and energy; and weighted median inflation. We examine the period 1985-2017. We find that both of the core-inflation measures filter out much of the transitory variation in the headline inflation rate due to industry price changes, but that the weighted median filters out more and therefore is less volatile.

Table 1 measures the volatility of each inflation series with the standard deviation of the change in inflation. We compute this statistic for both the CPI and PCE deflator versions of inflation. For both price indexes, we consider annualized monthly inflation rates, annualized quarterly inflation rates (measured with the percentage change in the price level from one quarter to the next), and the inflation rate over the previous twelve months (measured with overlapping 12-month intervals in monthly data).

The results in the Table are consistent across the two price indexes and the three data frequencies: the standard deviation of changes in inflation less food and energy is much smaller than that of headline inflation, but larger than that of weighted median inflation. The ratio of the standard deviations of changes in ex-food-energy and median inflation range from 1.4 to 1.6 (except for monthly PCE data, where the ratio is higher because of an outlier discussed below).

To illustrate these results, Figure 1 presents the monthly time series for the two measures of core inflation; in Figure 1A, both are based on the CPI measure of inflation, and in Figure 1B they are based on the PCE deflator. The greater volatility of the ex-food-energy measure of core is clear visually. In the CPI case, for example, in the late 1980s and early 1990s, median inflation generally fluctuates in a range of about 3-5%; CPIX inflation is often in that range but spikes up to 6% or 7% in a number of months. Stating in the late 1990s, CPIX spikes downward to zero or below in a number of months, whereas median inflation falls that far at only one point (February and March 2010).

The PCE deflator graph also shows that ex-food-energy inflation is more volatile than median inflation. Some of the months with outliers in PCEX inflation are also ones with outliers in CPIX inflation (such as March 2017, an observation that we examine closely below). But other times, the outlier months differ for CPIX and PCEX. For example, CPIX falls to 0.2% in April 2013 and then rises to 2.7% in July 2013; PCEX inflation is more stable, with rates of 0.7% in April and 1.2% in July. Evidently, the movements in ex-food-energy inflation caused by industry price changes can differ due to differences in the industries covered by the CPI and PCE and/or differences in how industry prices are measured

One episode produces large outliers in the PCEX data: the annualized inflation rate falls to -6.6% in September 2001 and then jumps to 8.6% in October. These numbers reflect huge but transitory movements in life insurance premiums in the wake of the September 11 terrorist attacks. These premiums fell at an annualized rate of -655% in September and then rebounded by 1457% in October. These changes in life insurance premiums were big enough to have major effects on monthly PCEX inflation. The weighted median, by contrast, filters out these prices changes along with less dramatic shocks.

Figure 2 shows the two measures of median inflation together: median CPI inflation and median PCE inflation. Usually, the two series move together fairly closely. It appears that the two medians are isolating more or less the same underlying level of inflation; the differences between the CPI and PCE price indices usually do not produce major differences in median inflation rates. The standard deviation of the difference between median CPI and median PCE is 0.7, compared to a standard deviation of 1.2 for the difference between CPIX and PCEX.

Figure 2 also reflects another similarity between median CPI and median PCE: their average levels over time are close. For 1985-2017, their average levels are 2.8% for median CPI and 2.7% for median PCE. By contrast, it is well known that the average levels of headline and ex-food-energy CPI inflation are higher than the corresponding series for PCE. For 1985-2017, the average levels of headline CPI and PCE are 2.6 and 2.2 percent respectively. The fact that the average level of median PCE exceeds the average level of headline PCE implies that, on average, there is some left skewness in the distribution of price changes across PCE industries.

4 A Case Study: Inflation in 2017-2018

Recent history helps us understand the value of weighted median inflation for understanding inflation movements. During 2017, the Fed's primary measure of core inflation, the 12-month inflation rate in PCEX, fell noticeably despite low unemployment, a development that Fed Chair Yellen called a "mystery" on several occasions. In trying to lessen the mystery, Yellen made ad hoc references to changes in prices in several industries, as well as "a whole range of idiosyncratic factors." We find that inflation behavior is less mysterious if we examine median inflation, which was stable over 2017 as a result of filtering out unusual industry price changes in a systematic way. Focusing on the median also helps us understand inflation in early 2018, when Fed policymakers puzzled over an uptick in 12-month PCE inflation.

Figure 3 shows inflation rates for PCEX and median PCE from January 2017 through March 2018. Panel A shows inflation rates over the previous 12 months, which is the focus of many discussions by economists and policymakers. We see the behavior of 12-month PCEX inflation that puzzled the Fed: It fell from 1.9 percent in January to 1.3 percent in August before rebounding to 1.8 percent in March 2018–a period when the unemployment rate fell from 4.8 to 4.1 percent. In discussing the low inflation rate in September, Chair Yellen said "I will not say that the [FOMC] clearly understands what the causes are."

The behavior of median PCE inflation is different. We see that this inflation rate starts three tenths of a percent above PCEX, in line with our finding above that average median PCE inflation is modestly higher than average PCEX inflation. For our purposes, however, the key fact about 12-month median inflation is that it is stable: throughout 2017, it stays in a range from 2.2 to 2.0. Policymakers would not have perceived a puzzling decline in core inflation if median were their measure of core.

Panel B of Figure 3 shows the monthly inflation rates underlying the smoother 12-month rates in Panel A. For PCEX, we see an important outlier: March 2017, when the PCEX inflation rate was -1.8%. This rate is 3.8 points below the Fed's inflation target of 2.0, so for twelve-month periods including March 2017, it pushes inflation (3.8)/12 = 0.32 points below the target. Other months in 2017 that help pull down the 12-month rate are May and November; in each of these months, the PCEX inflation rate is 0.9. For the median PCE, by contrast, one-month inflation rates in 2017 fluctuate in a relatively narrow range from 1.4 to 2.9, leading to a very stable series when inflation rates are averaged over twelve months.

For the influential month of March 2017, Figure 4 shows a histogram of industry price changes within the PCEX index; each bar represents an interval of 5 percentage points in inflation rates and shows the total weights of the industries in that range. We see how PCEX is pulled down by a tail of large price decreases–by left skewness in the distribution. Sizable industries with highly negative inflation rates include air transportation (weight of 0.5% in the PCEX index and inflation rate of -65%); communication (weight of 2.4% and inflation rate of -38%); hotels and motels (weight of 0.9% and inflation rate of -34%); and men's and boys' clothing (also weight of 0.9% and inflation rate of -34%). Smaller industries with highly negative inflation rates include watches and video cassettes and discs.

In a series of speeches and news conferences in 2017, Fed Chair Yellen sought to explain the low level of PCEX inflation. On several occasions (in June, September, and October), she cited a large decline in the quality adjusted prices of cell phone service that occurred when cell phone companies introduced unlimited data plans. In June, she also mentioned a drop in prescription drug prices. In November, she mentioned unexpectedly slow growth in health care costs in general, which she said was one of "a whole range of idiosyncratic factors" affecting inflation.

In these remarks, Yellen is trying in a haphazard way to do what the weighted median inflation rate does more easily and systematically: uncover stable inflation behavior by filtering out unusual industry price changes. Yellen is right about "a whole range of factors": a number of industries contribute to the negative PCEX inflation of March 2017, and others contribute to the low inflation of May and November. Yellen is also on target in specifically mentioning cell phones: a significant factor in the March 2017 outlier for PCEX inflation results from the -38% inflation rate in the communications sector. Cell phone services are one part of this sector that experienced an inflation rate of -84%.

One the other hand, Yellen's remark about prescription drugs is puzzling. Prices in this industry rose at an annual rate of 4.7% in March, and a rate of 3.4% for the 12 months of 2017, numbers that go in the wrong direction for explaining low PCEX inflation. Yellen is correct that some medical industries experienced low inflation rates in 2017; the rate for the year for physician's services, for example, was 0.5%. However, this rate is only modestly lower than the aggregate PCEX inflation rate. As we have discussed, theory suggests that only unusually large changes in relative prices affect aggregate inflation. In explaining inflation, it is suspect to point out industries with inflation rates modestly higher or lower than the aggregate, because there are many such industries at all times.

We conclude that it would have been easier for the Fed to accurately interpret core-inflation movements in 2017 if its core measure was weighted median inflation.[3]

It appears that policymakers' thinking about inflation might also have been more clear in early 2018 if they focused on median inflation. In the minutes of the FOMC meeting on May 1, some participants suggest that inflation is likely to overshoot the Fed's 2% target, noting "the recent increase in inflation." This increase appears to be the jump in 12-month PCEX inflation from 1.5% in February to 1.8% in March, the last month for which the Committee had data. Other Committee members downplay the importance of this increase, saying "it may have represented transitory price changes in some categories of health care and financial services."

[3] In her September speech, Yellen mentions briefly that trimmed mean inflation has fallen less than PCEX inflation, which is some acknowledgment of the usefulness of filtering out large industry price changes systematically.

These references to industry price changes, like some of Yellen's in 2017, are questionable. In the industry data, price changes in various health care industries are unremarkable. The minutes are correct that there was a large increase in the prices of financial charges, fees, and commissions: in March 2018, annualized inflation in that industry was 24%. But the contribution of this monthly increase to aggregate inflation is modest. The weight on the financial fees component in the PCEX is 0.3%, which means the 24% inflation in that industry accounts for 0.07 percentage points of annualized aggregate inflation for that month. That level of inflation in one month accounts for only 0.01 percentage points of 12-month inflation.

What then explains the apparent uptick in PCEX inflation? The answer is primarily that March 2018 is the month in which the -1.8% inflation rate in March 2017 drops out of the 12-month average. The behavior of PCEX within 2018 is a smaller factor: the average of the monthly inflation rates from January through March is 2.4%, a modest overshoot of the 2% target. A number of outside commentators (e.g., Rugaber, 2018, and Mutikani, 2018) note the role of March 2017 in explaining the change in 12-month inflation in March 2018, but this point does not appear in the FOMC minutes.

Once again, there is less inflation variability to explain when we examine the weighted median PCE. Over the first three months of 2018, neither the months being added to the 12-month average nor those being deleted are outliers, and 12-month median inflation is stable at 2.2%. The relative stability of monthly median inflation means that the 12-month inflation rate is not very sensitive to adding and deleting months at the ends of the 12-month window.

5 Phillips Curves

Many of the economists who have puzzled over recent inflation behavior have emphasized the apparent absence of an unemployment-inflation relationship consistent with a textbook Phillips curve. Here we examine how well a simple Phillips curve fits the quarterly data since 1985, and especially whether such a relationship has broken down since the onset of the Great Recession in 2008. We find that the answers depend on how inflation is measured. With headline inflation, the volatility in that variable means there is no discernable Phillips curve. When we examine core inflation as measured by CPIX or PCEX, the evidence is mixed and we can see why many analysts would not see a Phillips curve or believe it has broken down. By contrast, with median inflation, the data show a clear and robust Phillips curve, with no evidence of a significant change in the relationship after 2008.

Specification

We consider a simple version of Milton Friedman's (1968) expectations-augmented Phillips curve, in which the inflation rate depends on expected inflation and on deviations of the unemployment rate from its natural rate. Specifically, in quarterly data, we assume

$$\pi_t = \pi_t^e + \alpha\overline{(u - u^*)}_t + \epsilon_t, \tag{1}$$

where π is inflation, π^e is expected inflation, and $\overline{(u - u^*)}_t$ is the average of the unemployment rate, u, minus the natural rate, u^*, from $t - 3$ through t. Our inclusion of four quarterly lags follows previous research on the Phillips curve (e.g., Stock and Watson, 2010). For parsimony we restrict the coefficients on the current and three lags of $u - u^*$ to be the same, so only the average of the four appears in the equation (a restriction that we cannot reject in the data).

Again following previous work (e.g., Fuhrer and Olivei, 2010; Ball and Mazumder, 2018), we measure expected inflation with long-term inflation forecasts, specifically, the mean of ten-year forecasts from the Survey of Professional Forecasters (π^F). When we measure inflation with any version of the consumer price index (whether headline or one of the core measures), we use ten-year forecasts of CPI inflation. When we measure inflation with the PCE, we have the problem that ten-year SPF forecasts of PCE inflation only started in 2007. We use these forecasts for the period when they are available. As a proxy for PCE expectations before then, we use the forecasts of CPI inflation minus the average difference between the CPI and PCE forecasts for the period when both are available (which is 0.23).

We measure the natural rate of unemployment, u^*, with the trend in unemployment from the Hodrick-Prescott filter with a smoothing parameter of 1600. We eschew more sophisticated methods for estimating the natural rate, such as Staiger et al. (1997), because they involve estimating u^* along with the parameters of an assumed Phillips curve. This approach can bias the estimates of u^* in the direction of fitting a Phillips curve relationship even if none exists, a problem that does not arise with our univariate approach to estimating u^*.

To estimate the Phillips curve, we move our measure of expected inflation to the left side of the equation and estimate:

$$\pi_t - \pi_t^e = \alpha\overline{(u - u^*)}_t + \epsilon_t. \tag{2}$$

This equation does not include a constant term: when $u - u^*$ is zero, Friedman's Phillips curve says $\pi - \pi^e$ should equal zero. However, for some of the Phillips curves we estimate, a constant term is statistically significant when we allow one. To capture the unemployment-inflation relationship in the data, we estimate our equation with a constant added as well as without a constant. Arguably, whether the estimated constant is close to zero is one test of whether the Phillips curve fits the data well. We do not put too much weight on this test, however, because a constant could also capture measurement error in our variables that has a non-zero mean.[4]

[4]In particular, the HP filter forces the mean of the difference $u - u^*$ to be zero. Other estimates suggest a non-zero mean over our sample period of 1985-2017; for example, the Congressional Budget Office's series for u* implies that the mean of u-u* was +0.78.

Estimates for 1985-2017

Table 2 presents Phillips curve estimates with inflation measured with the CPI, and Table 3 presents estimates with the PCE deflator. In each case, we compare the performance of headline inflation, inflation less food and energy, and weighted median inflation. For the regressions with inflation less food and energy and the median, Figures 5 (for CPI) and 6 (for PCE) present scatterplots of the data underlying the regressions.

In the Tables, the first column gives results for our entire sample period. We first examine those results and then turn to subsamples.

The full-sample results make it clear, first, that the fit of the Phillips curve is highly sensitive to the choice between headline and core inflation. For either the CPI or the PCE measures of inflation, it is easy to see how someone who examines headline inflation could be skeptical of the existence of a Phillips curve. The estimates of the Phillips curve slope α are insignificant and the $\overline{R}^2$s for the estimated equations are negative (either with or without a constant). The large amount of noise in quarterly headline inflation obscures any underlying Phillips curve.

Our results are also influenced by our choice of a core-inflation measure–to a substantial degree for CPI inflation and even more for PCE inflation. For CPI inflation less food and energy, the Phillips curve slope is significant at the 5% level, but the $\overline{R}^2$ is negative with no constant term and only 0.22 with a constant. The fit is better with weighted median CPI, as we can see from the $\overline{R}^2$ of 0.48 with a constant term and 0.41 without. The good fit of the no-constant specification partly reflects the fact that, when a constant is included, it is smaller than the constant in the CPIX equation. The scatter plots in Figure 5 confirm visually that a Phillips curve appears more clearly in the data for median CPI than for CPIX.

When we turn to PCE inflation, the differences between the results for the ex-food-energy and median measures of core inflation become stronger. For PCEX, the $\overline{R}^2$ for the Phillips curve is negative without a constant and only 0.07 with a constant; for median PCE, the $\overline{R}^2$

is 0.32 in both cases, and the estimated constant is close to zero. In Figure 6, we again get visual confirmation of the difference in fit.

Some researchers damn the Phillips curve with faint praise, saying there is evidence for such a relationship but that it is flat–the effect of unemployment on inflation is small–and the residuals are large. Blanchard (2016), for example, finds an unemployment coefficient of about -0.2 since the 1990s and a residual with a standard error of about 1.0. According to our results, when the Phillips curve is estimated for median inflation, the coefficient is larger in absolute value: -0.48 for median PCE and -0.65 or -0.66 for median CPI. The standard errors of the residuals are between 0.4 and 0.5.

Has the Phillips Curve Taken a Vacation?

Economists such as Blinder (2018) say there was once evidence for a Phillips curve, but that the relationship has disappeared over the decade since the onset of the Great Recession. Our findings on this question depend on how core inflation is measured, even more strongly than before. When the sample period is restricted to 2008-2017, the fit of the Phillips curve becomes weaker for inflation less food and energy, but stronger for median inflation.

These results can be seen with scatter plots of our data for 2008-2017, given in Figures 7 and 8, and the regression results in the middle columns of Tables 2 and 3. For median inflation, the fit of the Phillips curve is quite good in all cases: $\overline{R}^2$s range from 0.54 to 0.64 and the estimated constant terms are close to zero. The estimated coefficients on unemployment are close to those for the full sample since 1985. Figure 7B and 8B both show a clearly negative unemployment-inflation relationship that passes near the origin of the graph. Based on these results, we suspect economists would not speculate so much about the demise of the Phillips curve if they examined the behavior of median inflation.

For the CPIX measure of core inflation, the evidence of a post-2008 Phillips curve is borderline. The unemployment coefficient is significant at the 5% level when a constant term is included in the equation but not without a constant. We can also see in Figure 7A that the results depend heavily on two observations in the lower right of the graph: quarters 1 and 2 of 2010, when the unemployment gap was at its highest levels in the sample and inflation was its lowest. If we exclude these two observations, the Phillips curve slope is far from significant.

For the PCEX measure of core inflation, it appears that there has been no Phillips curve since 2008. In the regressions, unemployment has no explanatory power for inflation ($\overline{R}^2$=0.001 with a constant). In Figure 8A, we see that $\pi - \pi^e$ is almost always negative–inflation has persistently fallen short of its expected level–and that inflation and unemployment appear unrelated. It is not surprising that economists have been puzzled by the behavior of PCEX, the Fed's preferred measure of core inflation.

6 Conclusion

...To come...

References

Ball, L. and N. Mankiw (1995): "Relative-Price Changes as Aggregate Supply Shocks," *The Quarterly Journal of Economics*, 110, 161–93.

Ball, L. and S. Mazumder (2011): "Inflation Dynamics and the Great Recession," *Brookings Papers on Economic Activity*, 337–405.

——— (2018): "A Phillips Curve with Anchored Expectations and Short-Term Unemployment," *Journal of Money, Credit and Banking*, 0.

Bank of Canada (2016): "Background Information-October 2016," *Renewal of the Inflation-Control Target*.

Bernstein, J. (2017): "Two inflation puzzles, one inflation monster," *The Washington Post*.

Blanchard, O. (2016): "The Phillips Curve: Back to the '60s?" *American Economic Review*, 106.

Blinder, A. (2018): "Is the Phillips Curve Dead? And Other Questions for the Fed," *The Financial Times*.

Brischetto, A. and A. Richards (2006): "The Performance of Trimmed Mean Measures of Underlying Inflation," RBA Research Discussion Papers rdp2006-10, Reserve Bank of Australia.

Bryan, M. and S. Cecchetti (1994): "Measuring Core Inflation," in *Monetary Policy*, NBER, NBER Chapters.

Bryan, M., S. Cecchetti, and R. Wiggins (1997): "Efficient Inflation Estimation," *NBER Working Paper*, 6183.

Clark, T. (2001): "Comparing measures of core inflation," *Federal Reserve Bank of Kansas City Economic Review*, 5–31.

Coibion, O. and Y. Gorodnichenko (2015): "Is the Phillips Curve Alive and Well after All? Inflation Expectations and the Missing Disinflation," *American Economic Journal: Macroeconomics*, 7, 197–232.

Crone, T., N. Khettry, L. Mester, and J. Novak (2013): "Core measures of inflation as predictors of total inflation," *Journal of Money, Credit and Banking*, 45, 505–519.

Dolmas, J. (2005): "Trimmed mean PCE inflation," Working Papers 0506, Federal Reserve Bank of Dallas.

Friedman, M. (1968): "The Role of Monetary Policy," *American Economic Review*, 58, 1–17.

Fuhrer, J. and G. Olivei (2010): "The role of expectations and output in the inflation process: an empirical assessment," *Federal Reserve Bank of Boston Public Policy Brief.*

Gamber, E. and J. Smith (2016): "Time-series measures of core inflation," Working Papers 2016-008, The George Washington University, Department of Economics, Research Program on Forecasting.

Mutikani, L. (2018): "US Annual Inflation Measures Jump as Consumer Spending Rises," *Reuters.*

Rugaber, C. (2018): "US consumer prices in March rose 2.4 pct. from year earlier," *Associated Press.*

Smith, J. (2004): "Weighted Median Inflation: Is This Core Inflation?" *Journal of Money, Credit and Banking*, 36, 253–263.

Staiger, D., J. Stock, and M. Watson (1997): "How Precise Are Estimates of the Natural Rate of Unemployment?" in *Reducing Inflation: Motivation and Strategy*, ed. by C. Romer and D. Romer, University of Chicago Press, 195–246.

Stock, J. (2011): "Discussion of Ball and Mazumder, "Inflation Dynamics and the Great Recession"," *Brookings Papers on Economic Activity*, 387–402.

Stock, J. and M. Watson (2007): "Why Has U.S. Inflation Become Harder to Forecast?" *Journal of Money, Credit and Banking*, 39, 3–33.

——— (2010): "Modeling inflation after the crisis," *Proceedings - Economic Policy Symposium - Jackson Hole*, 173–220.

Summers, L. (2017): "America needs its unions more than ever," *The Financial Times.*

The Economist (2017): "The Phillips Curve may be broken for good," *The Economist.*

Table 1: Volatility of Alternative Inflation Measures

	Monthly	Quarterly	12-Month
Headline CPI	3.278	2.307	0.387
CPIX	1.403	0.653	0.131
Median CPI	0.916	0.447	0.095
Headline PCE	2.408	1.567	0.268
PCEX	1.633	0.681	0.134
Median PCE	0.868	0.436	0.085

Note: The numbers in the table are standard deviations of the change in the annualized inflation rate over 1985-2017. The monthly numbers for headline PCE, PCEX, and median PCE inflation are 2.36, 1.36, and 0.89 respectively when September-November 2001 are excluded.

Table 2: Phillips Curves with CPI Inflation

$\pi_t - \pi_t^F = \alpha\overline{(u - u^*)}_t + \epsilon_t$						
	CPI Inflation					
	1985Q1-2017Q4		1985Q1-2007Q4		2008Q1-2017Q4	
$Constant$		-0.355		-0.259		-0.715
		(0.173)		(0.175)		(0.397)
α	-0.195	-0.224	-0.626	-0.699	0.256	0.349
	(0.312)	(0.331)	(0.226)	(0.254)	(0.612)	(0.647)
$\overline{R}^2$	-0.031	-0.02	0.037	0.058	-0.068	-0.013
$S.E.of Reg$	1.884	1.857	1.426	1.410	2.628	2.561
	CPIX Inflation					
	1985Q1-2017Q4		1985Q1-2007Q4		2008Q1-2017Q4	
$Constant$		-0.319		-0.250		-0.502
		(0.065)		(0.071)		(0.100)
α	-0.424	-0.450	-0.448	-0.519	-0.399	-0.334
	(0.181)	(0.128)	(0.186)	(0.162)	(0.291)	(0.161)
$\overline{R}^2$	-0.052	0.216	0.051	0.220	-0.487	0.178
$S.E.of Reg$	0.627	0.541	0.573	0.519	0.743	0.553
	Median CPI Inflation					
	1985Q1-2017Q4		1985Q1-2007Q4		2008Q1-2017Q4	
$Constant$		-0.167		-0.158		-0.183
		(0.061)		(0.069)		(0.102)
α	-0.648	-0.661	-0.598	-0.643	-0.699	-0.676
	(0.117)	(0.093)	(0.109)	(0.099)	(0.189)	(0.146)
$\overline{R}^2$	0.408	0.480	0.309	0.381	0.543	0.601
$S.E.of Reg$	0.468	0.439	0.465	0.440	0.476	0.445

Note: OLS with robust (HAC) standard errors is used (standard errors in parentheses). The unemployment gap is the deviation of the unemployment rate from the HP filtered series, where the filter is applied over 1948-2017.

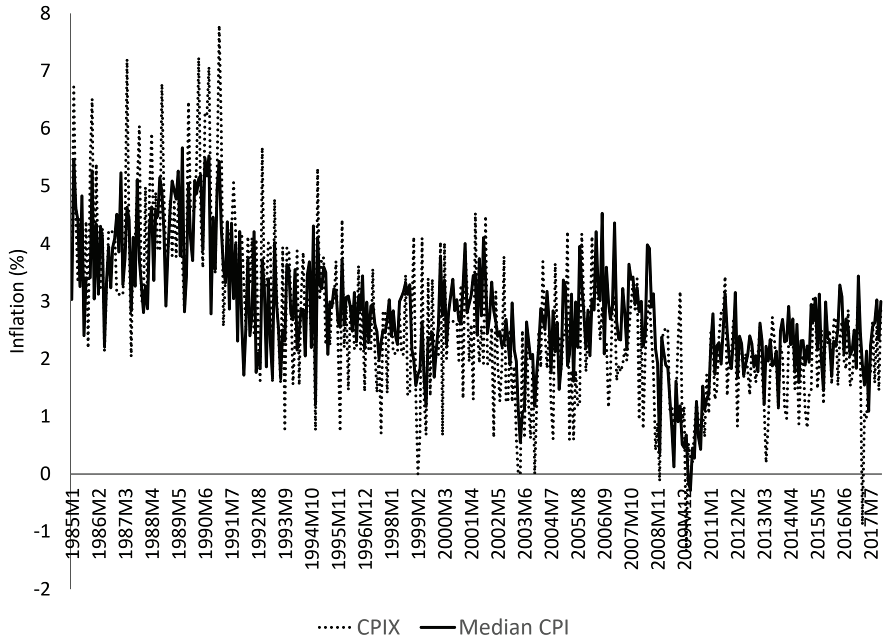
Table 3: Phillips Curves with PCE Inflation

$\pi_t - \pi_t^F = \alpha\overline{(u-u^*)}_t + \epsilon_t$						
	PCE Inflation					
	1985Q1-2017Q4		1985Q1-2007Q4		2008Q1-2017Q4	
$Constant$		-0.533		-0.523		-0.669
		(0.138)		(0.152)		(0.289)
α	-0.093	-0.136	-0.388	-0.535	0.215	0.303
	(0.233)	(0.264)	(0.192)	(0.235)	(0.433)	(0.455)
$\overline{R}^2$	-0.156	-0.003	-0.149	0.057	-0.129	-0.006
$S.E.of Reg$	1.435	1.337	1.198	1.086	1.856	1.752
	PCEX Inflation					
	1985Q1-2017Q4		1985Q1-2007Q4		2008Q1-2017Q4	
$Constant$		-0.531		-0.543		-0.544
		(0.063)		(0.078)		(0.089)
α	-0.201	-0.244	-0.231	-0.385	-0.169	-0.098
	(0.148)	(0.080)	(0.162)	(0.108)	(0.241)	(0.116)
$\overline{R}^2$	-0.785	0.066	-0.668	0.108	-1.207	0.001
$S.E.of Reg$	0.768	0.555	0.786	0.575	0.733	0.493
	Median PCE Inflation					
	1985Q1-2017Q4		1985Q1-2007Q4		2008Q1-2017Q4	
$Constant$		0.017		0.030		-0.021
		(0.062)		(0.084)		(0.047)
α	-0.478	-0.477	-0.505	-0.496	-0.451	-0.448
	(0.078)	(0.079)	(0.133)	(0.136)	(0.079)	(0.074)
$\overline{R}^2$	0.319	0.315	0.221	0.215	0.642	0.635
$S.E.of Reg$	0.445	0.446	0.503	0.505	0.272	0.275

Note: OLS with robust (HAC) standard errors is used (standard errors in parentheses). The unemployment gap is the deviation of the unemployment rate from the HP filtered series, where the filter is applied over 1948-2017.

Figure 1: CPI and PCE Core Monthly Inflation

(a) CPI



(b) PCE

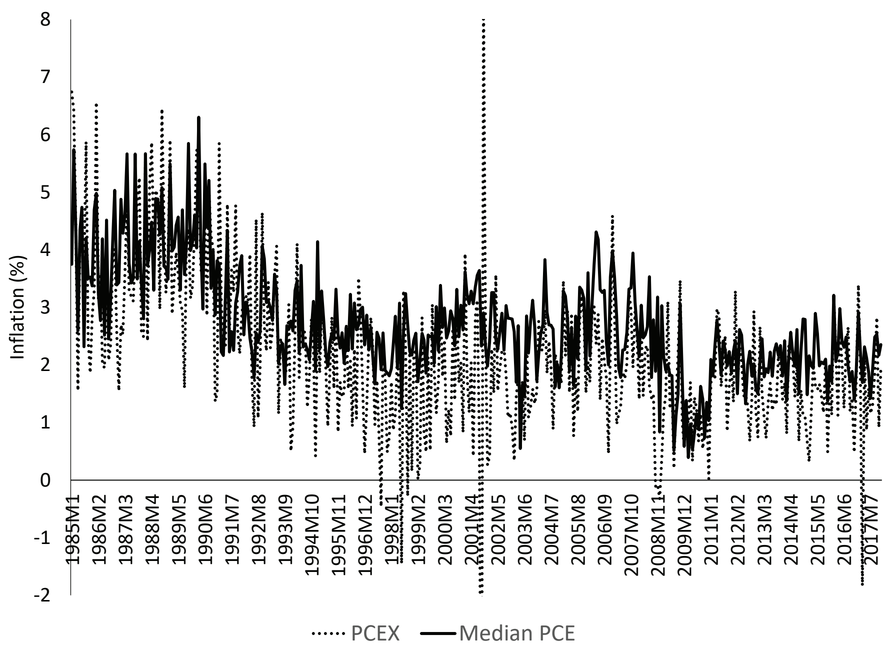


Figure 2: Median CPI and Median PCE Monthly Inflation

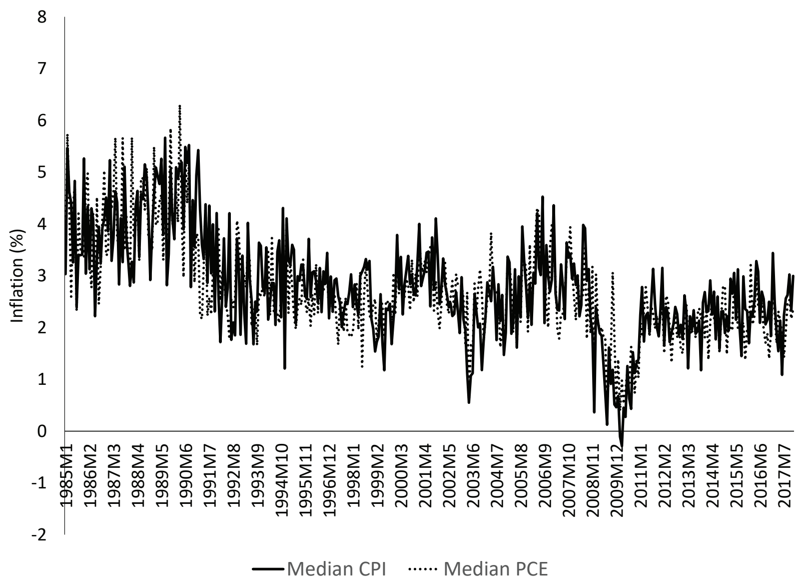
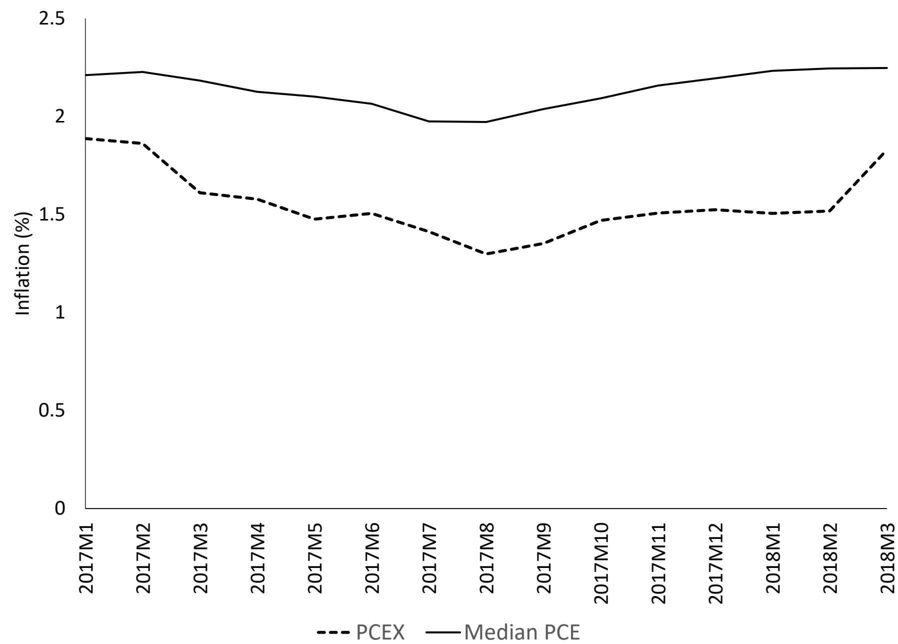


Figure 3: PCEX and Median PCE Inflation, January 2017-March 2018

(a) 12-Month



(b) 1-Month

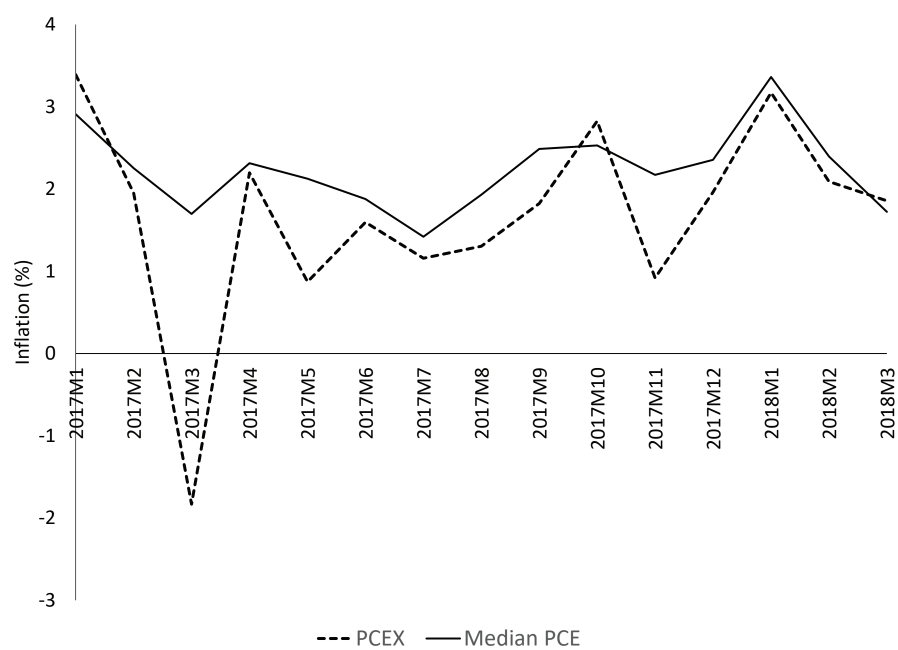
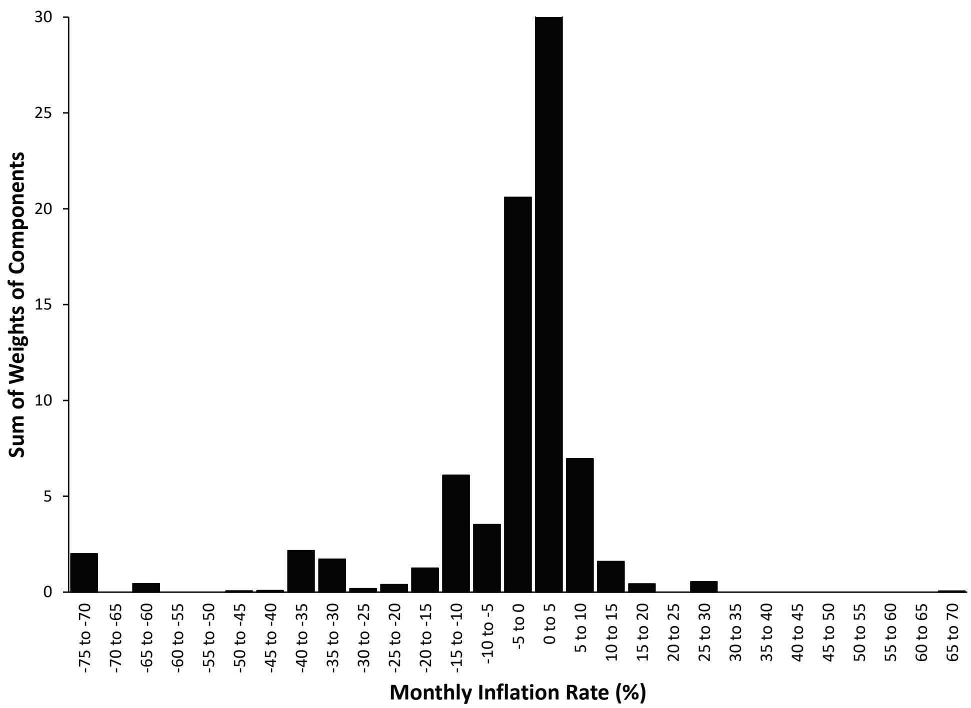


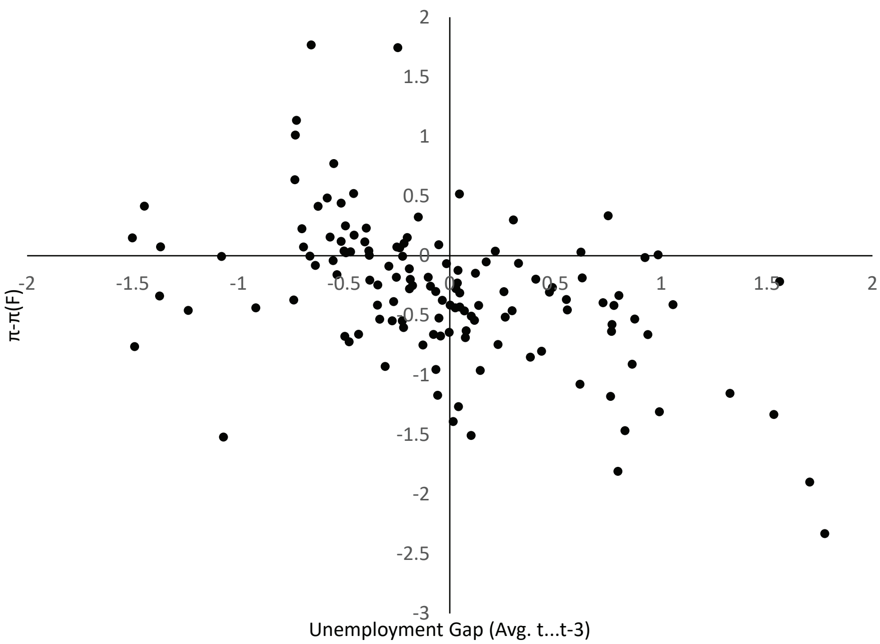
Figure 4: Histogram of Industry Price Changes in March 2017



Note: The vertical axis is cut off at 30–the sum of industries weights in the 0 to 5% inflation rate range is 51.7. Industries in tails: gasoline and other motor fuel (-75 to -70), air transportation (-65 to -60), watches (-50 to -45), video cassettes and discs (-40 to -35), communication (-40 to -35), and children's and infants' clothing, hotels and motels, and men's and boys' clothing (-35 to -30) in the lower tail, and prerecorded and blank audio discs/tapes/digital files/downlowads (65 to 70) in the upper tail.

Figure 5: Scatterplots of π-π^F vs. Unemployment Gap, CPI Inflation, 1985-2017

(a) CPIX



(b) Median CPI

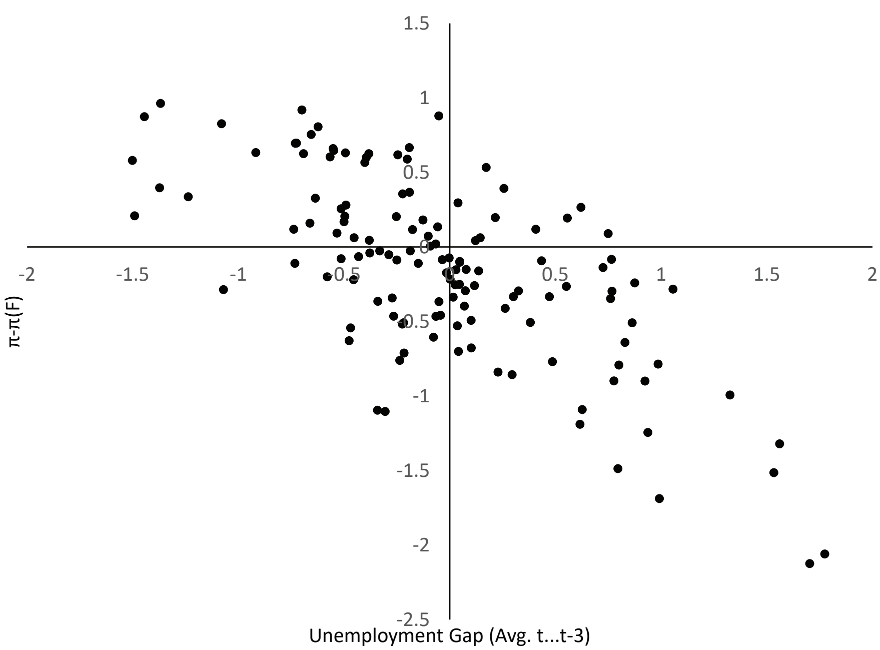
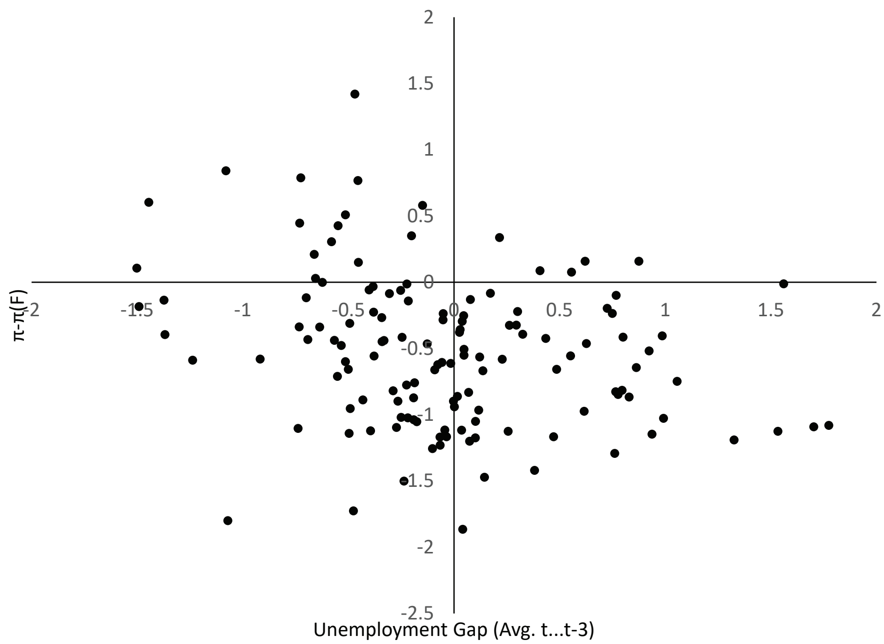


Figure 6: Scatterplots of π-π^F vs. Unemployment Gap, PCE Inflation, 1985-2017

(a) PCEX



(b) Median PCE

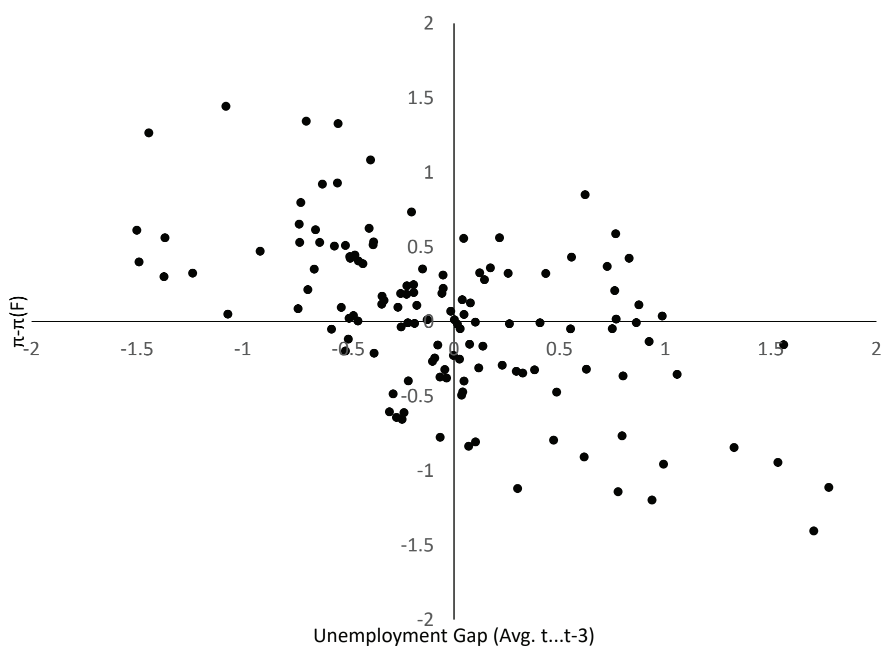
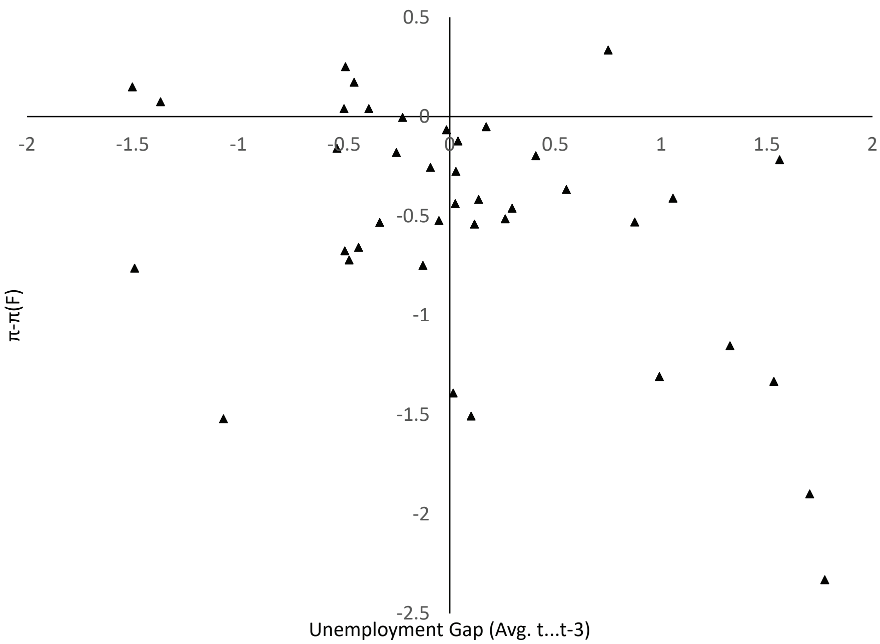


Figure 7: Scatterplots of π-π^F vs. Unemployment Gap, CPI Inflation, 2008-2017

(a) CPIX



(b) Median CPI

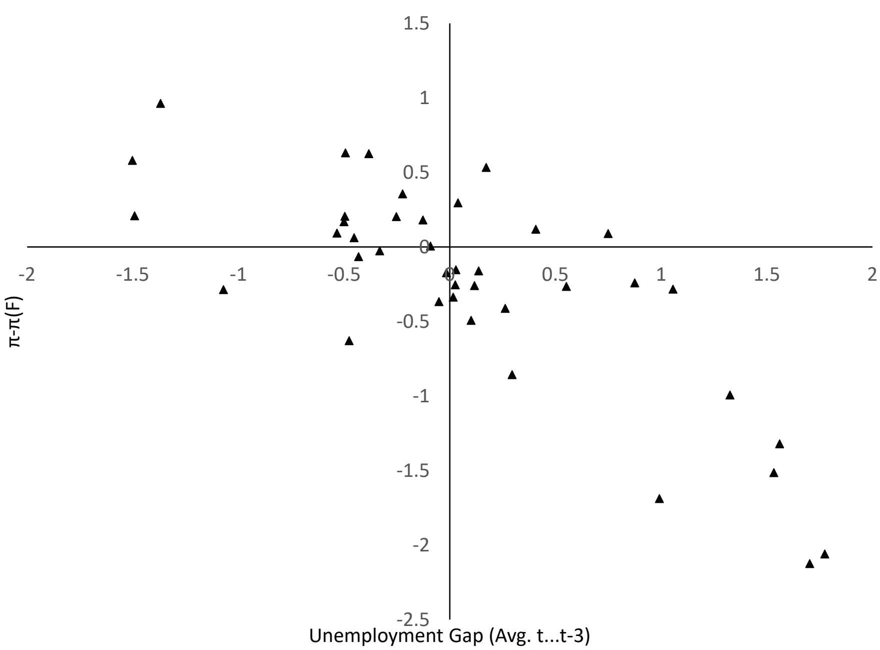
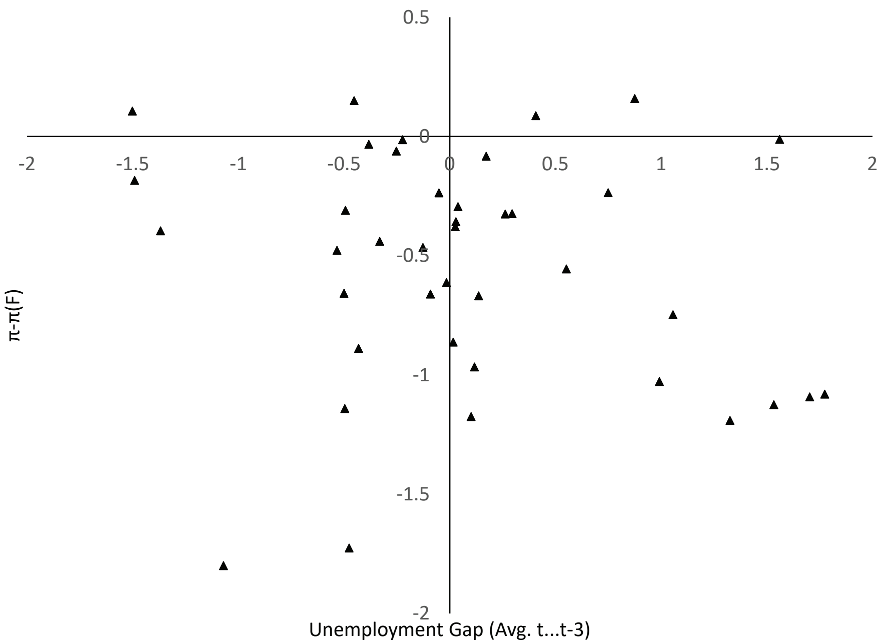


Figure 8: Scatterplots of π-π^F vs. Unemployment Gap, PCE Inflation, 2008-2017

(a) PCEX



(b) Median PCE