A PHILLIPS CURVE FOR THE EURO AREA

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NBER Working Paper No. 26450
November 2019
JEL No. E31,E32

ABSTRACT

This paper asks whether a textbook Phillips curve can explain the behavior of core inflation in the euro area. A critical feature of the analysis is that we measure core inflation with the weighted median of industry inflation rates, which is less volatile than the common measure of inflation excluding food and energy prices. We find that fluctuations in core inflation since the creation of the euro are well explained by three factors: expected inflation (as measured by surveys of forecasters); the output gap (as measured by the OECD); and the pass-through of movements in headline inflation. Our specification resolves the puzzle of a "missing disinflation" after the Great Recession, and it diminishes the puzzle of a "missing inflation" during the recent economic recovery.

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1 Introduction

The behavior of European inflation over the last decade has puzzled economists and policy-makers. The puzzle has two parts: a "missing disinflation" in the wake of the twin recessions of 2008 and 2011, and a "missing inflation" more recently as the economy has recovered. Both parts of the puzzle are apparent failures of inflation to respond to the level of economic slack in the way predicted by a conventional Phillips curve.

Researchers have suggested many possible factors behind the puzzles. For example, economists at the European Central Bank have considered a de-anchoring of inflation expectations, an increase in the persistence of shocks to the inflation rate, non-linearity or time-variation in the effects of slack on inflation, and changes in commodity prices and exchange rates (Ciccarelli and Osbat, 2017; Bobeica and Sokol, 2019). Recently, top ECB officials have suggested that inflation behavior has been influenced by structural changes in the economy, such as digitalization and globalization (Draghi, 2019) and the growth of the service sector (Coueré, 2019).

This paper argues that European inflation behavior is not as puzzling or complex as recent discussions suggest. A simple Phillips curve captures most of the movements in inflation over the twenty years that the Euro has existed.

Like many researchers, we examine a measure of *core* inflation that strips out the effects of large relative price changes on headline inflation. We do not, however, focus on the most common measure of core inflation, the inflation rate excluding food and energy prices. Instead, our preferred measure is the weighted median of industry inflation rates, a concept developed by Bryan and Cecchetti (1994) that we also use in research on U.S. inflation (Ball and Mazumder, 2019). In both the U.S. and Europe, weighted median inflation is less volatile and easier to explain than the conventional core measure. Section 2 of this paper examines the behavior of the two core inflation series since 1999.

We have two main specifications of the Phillips curve. The first, presented in Section

3, relates quarterly core inflation to expected inflation, as measured by five-year forecasts from the Survey of Professional Forecasters, and the Euro area output gap, as measured by the OECD. Expected inflation does not vary much over our sample period, so our equation is close to a relationship between core inflation and the output gap alone. This equation explains a large fraction of the movements in weighted median inflation ($\overline{R}^2$=0.64), but substantial residuals remain, including inflation rates that are higher than their predicted levels over 2010-2013 and lower since then.

Our second specification, examined in Section 4, adds one more variable to the equation for core inflation: the deviation between headline and core inflation over the current and previous three quarters. This specification captures the idea that movements in headline inflation are partially passed through into core inflation through wage adjustment and the cost of intermediate inputs. This idea appears in some previous research on European inflation (e.g. Peersman and Van Robays, 2009; ECB Monthly Bulletin, 2014).

Adding this new variable to the Phillips curve produces a substantial improvement in fit ($\overline{R}^2$=0.76), and it largely eliminates the perceived puzzles about inflation over the last decade. Based on our specification, there is no missing disinflation, and only a modest amount of missing inflation that arises in 2017-2018.

Section 5 extends our analysis to the United States with the goal of comparing European and U.S. inflation behavior. We find one important difference: the pass-through of headline to core inflation that occurs in Europe does not occur in the U.S. This difference might be explained by differences in wage determination in the two economies.

2   Core Inflation in the Euro Area

This paper seeks to explain the quarterly behavior of core inflation, as measured by the weighted median inflation rate. Here we describe this variable and compare it to the inflation rate excluding food and energy prices (XFE inflation), which is the most common

measure of core inflation. We also examine the movements of weighted median inflation over 1999-2018 to see what facts we need to explain.

Measuring Core Inflation

We construct the weighted median inflation rate from the inflation rates in the 94 industries that make up the HICP price index for the Euro area, and the industries' weights in the index. The weighted median is the inflation rate such that industries with half of the total weights have higher rates and industries with half of the weights have lower rates.

Our previous work (Ball and Mazumder, 2011 and 2019) discusses the theoretical and empirical case for measuring core inflation with the weighted median. The basic idea is that this variable filters out the transitory effects on inflation of large relative price changes caused by microeconomic factors. XFE inflation filters out large price changes in food and energy industries, but many other industries also experience large price changes. The weighted median filters out large shocks in *all* industries, producing a less volatile measure of underlying inflation.

Figure 1 compares the weighted median and XFE inflation rates over 1999-2008. We examine these variables at three frequencies: monthly, quarterly, and a four-quarter moving average. We can see that monthly XFE inflation is quite a bit more volatile than monthly median inflation: the standard deviation of changes in inflation is 0.93 for XFE and 0.51 for median. This difference diminishes at higher levels of time aggregation, but the standard deviation is still larger for XFE (by a factor of 1.22 for quarterly data and 1.09 for 4-quarter averages).[1]

One period in which XFE inflation is especially volatile is the last two years of the sample, 2017-2018. During those years, annualized monthly rates of XFE inflation vary over

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[1]We derive a series for monthly median inflation from monthly data on industry inflation rates, and multiply by 12 to produce annualized monthly rates. To derive quarterly median inflation, we convert monthly median inflation to monthly price levels, average over three months to get quarterly price levels, compute the percentage change from the previous to the current quarter, and multiply by four to annualize.

a four-percentage-point range, from -1.3% to 2.7%. Median inflation rates vary by only one percentage point, from 0.8% to 1.8%.

To understand why the XFE series can be volatile, consider the month of October 2017, when XFE inflation is -1.3% and median inflation is +1.3%. For that month, Figure 2 shows a histogram of industry price changes within the XFE index. Each bar in the graph represents an interval of 5 percentage points in annualized inflation rates and shows the total weights in the index of industries in that range. We see a large tail of price decreases that skews the distribution to the left and pulls down XFE inflation, but not median inflation. Eight industries with total weights of about 7% have annualized inflation rates below -10%, including education (-31%) and transport insurance (-26%), while no industry has an inflation rate above +10%.[2]

The two core inflation rates differ somewhat in their average levels: for 1999-2018, average annual inflation is 1.71% for median and 1.45% for XFE. The average of headline HICP inflation is also 1.71%, the same to two decimal places as average median inflation. This fact means that large price changes that shift headline but not median inflation are balanced over time between large decreases (like those in October 2017) and large increases. The fact that XFE inflation is lower on average than headline inflation means that the relative price of food and energy rose over the sample period.

The Inflation Puzzles

In Figure 1C, which shows four-quarter averages of core inflation, we also show the two recessions that have occurred in the Euro area (as dated by the CEPR): the double dip in 2008Q1-2009Q2 and 2011Q3-2013Q1 associated with the global financial crisis and the European debt crisis. Much of the recent discussion of European inflation concerns the responses

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[2]There are stories behind the large price decreases in October 2017. The fall in education prices reflects a decrease in university tuition in Italy. The fall in transport insurance prices reflects a decrease in insurance premiums in Germany. (See Lis and Porqueddu (2018) in the ECB Economic Bulletin.)

or lack thereof to the recessions and the recovery since 2013, which are often characterized as a "missing disinflation" and a "missing inflation."

The Figure suggests that reports of a missing disinflation are a bit misleading, because the first recession pushed inflation down significantly: the four-quarter average of median inflation fell from 2.9% in 2008Q3 to 1.1% to 2010Q2. What may be more surprising is that inflation rebounded sharply between the two recessions, reaching 2.2% in 2011Q4, so the net decrease from 2008 to late-2011 was modest. The second recession led to a second fall in inflation, to 0.9% in 2015Q1.

In recent years, there has been a missing inflation in the sense that inflation has persistently fallen short of the ECB's target of "below but close to 2%." Inflation has risen somewhat, however, as the economy has recovered from the recessions: four-quarter median inflation rose from 0.9% in 2016Q2 to 1.5% in 2018Q4. Notice that four-quarter XFE inflation was only 1.2% in 2018Q4, so the common focus on this core inflation measure has magnified the apparent missing-inflation puzzle.

In the rest of this paper, we ask how well the ups and downs of inflation in Figure 1 can be explained by simple Phillips curves.

3   The Basic Phillips Curve

Here we examine a simple version of a textbook Phillips curve and find that it explains a large fraction of the fluctuations in core inflation in Figure 1, especially when core inflation is measured by weighted median inflation.

Specification and Data

Following Milton Friedman (1968), we assume that core inflation is determined by expected inflation and the level of slack in the economy. Here, we measure slack with the gap between

output and potential output, as estimated by the OECD. In an Appendix, we consider the robustness of our results with the other common measure of slack, the deviation of unemployment from its natural rate.

Specifically, we assume that quarterly core inflation is determined by:

$$\pi_t = \pi_t^e + \alpha \overline{(y - y^*)}_{t-1} + \epsilon_t, \tag{1}$$

where π is the annualized core inflation rate, π^e is expected inflation, and $\overline{(y - y^*)}_{t-1}$ is the log difference between the four-quarter averages of actual and potential output from $t - 4$ through $t - 1$. In assuming that quarterly inflation depends on slack over four quarters, we follow previous research on the U.S. Phillips curve.[3]

We compare results with the core inflation rate measured with the weighted median and with XFE inflation. For expected inflation, we use 5-year forecasts of inflation from the European Survey of Professional Forecasters. These forecasts are highly stable over our twenty-year sample: they always lie in a range from 1.8 to 2.0. Therefore, in practice our specification is close to one in which π^e is constant and the output gap is the only variable explaining movements in core inflation.

Our data on actual output come from Eurostat, and we derive potential output from actual output and OECD estimates of the output gap. The actual output data are quarterly but the output gap estimates and implied levels of potential are only available annually. We must therefore adapt the annual series for potential output for use in our quarterly regressions. This task is made easier by the fact that the output-gap variable in our equation is measured over four quarters. We interpret our estimate of potential in a year as a four-quarter average of potential through the fourth quarter of the year; take logs of these

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[3]See, for example, Stock and Watson (2009) and Ball and Mazumder (2019). The exact timing of lags varies in previous work, and it is not clear what is best. We have also estimated a version of equation (1) that includes the output gap from $t-3$ through t, rather than $t-4$ through $t-1$. That change increases the $\overline{R}^2$ of the equation modestly, from 0.64 to 0.67. However, the same change reduces the $\overline{R}^2$, from 0.76 to 0.73, for the augmented Phillips curve that includes the deviation of headline from median inflation (equation (2) below).

fourth-quarter observations; and then linearly interpolate to estimate the log of four-quarter averages of potential in quarters 1, 2, and 3. We subtract the resulting quarterly series from the log of the four-quarter average of actual output to obtain the four-quarter output gap series in our regressions.

Estimates for Alternative Core-Inflation Measures

Table 1 presents estimates of equation (1) with core inflation measured with median inflation and with XFE inflation. In each case, we present results with and without a constant term added to the equation. The theory underlying the Phillips curve implies that the constant should be zero: when the output gap is zero, inflation should equal expected inflation. Therefore, one test of the theory is whether the estimated constant is zero.

When the dependent variable is median inflation, the fit of the Phillips curve is good. The $\overline{R}^2$ is 0.64 with no constant included, and when the constant is added it is small and statistically insignificant. The coefficient on the output term (with no constant) is 0.23: a one percentage point increase in the average output gap over the previous four quarters raises the inflation rate by a bit less than one quarter of a percentage point.

When the dependent variable is XFE inflation, the coefficients on the output gap are close to those for median inflation. But the fit of the equation is substantially worse: the $\overline{R}^2$ is 0.21 without a constant and 0.46 with a constant. This deterioration reflects the relatively large transitory fluctuations in XFE inflation shown in Figure 1, which are not explained by the output gap. When the constant is included, it is significant with an estimated value of -0.32. This result implies that XFE inflation falls short of expected inflation by an economically meaningful amount when output is at potential.

Fitted Values for Median Inflation

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How well does our Phillips curve explain the inflation movements that have puzzled observers? To help answer this question, Figure 3 compares the path of median inflation to the fitted values from our estimated equation for that variable, with no constant (the first column of Table 1). Figure 3A shows the results for quarterly data, and Figure 3B shows smoother series created by taking four-quarter moving averages of actual and fitted inflation rates. The Figure confirms the fact, indicated by the $\overline{R}^2$ of our regression, that the equation captures most of the broad movements in median inflation.

The differences between actual and fitted values show, however, that the puzzles about inflation since the Great Recession are not fully resolved. The fitted values match the actual fall in inflation from 2008Q3 to 2010Q2 fairly well, but fail to explain most of the rise in inflation over 2010Q2-2011Q4. This pattern produces a significant amount of missing disinflation in the sense that actual four-quarter inflation in 2011Q4 (2.16%) exceeds the level predicted by our equation (1.62%).

Consistent with suggestions of a more recent missing inflation, actual four-quarter inflation is lower than its fitted values from 2014Q3 to the end of the sample. However, the differences between the two series are modest, peaking at 0.37 percentage points in 2016Q2, when actual inflation is 0.86% and the fitted value is 1.23%. In 2018Q4, actual four-quarter inflation is 1.52% and the fitted value is 1.76%. Inflation rates after 2014 are well below the ECB's "close-to-2-percent" target, but only part of this shortfall is a puzzle. Part of it is explained by a negative output gap, albeit one that diminishes to near zero at the end of the sample.

4 Pass-Through from Headline to Core Inflation

Here we show that the fit of our Phillips curve improves substantially if we add one more variable to the equation: a four-quarter moving average of the difference between headline and median inflation.

Motivation

Our analysis is motivated by a look at Figure 4. This Figure shows the two series from Figure 3B–the four-quarter averages of median inflation and of the fitted values from our basic Phillips curve–and adds the four-quarter average of headline inflation. The graph reveals a relationship between headline inflation and the residuals in our basic Phillips curve, which suggests that headline-inflation movements can help explain median inflation.

In particular, the major ups and downs in headline inflation since 2008 seem to pull median inflation in the same direction relative to the predictions of the basic Phillips curve. Headline inflation goes through a cycle in which it falls below median inflation over 2008Q4-2009Q4, then rises above median inflation over 2010Q1-2013Q1, then falls below it again over 2013Q2-2016Q4. Median inflation moves toward headline inflation in each part of this cycle.

We have emphasized that large price changes in any industry can influence headline inflation. However, the broad movements in headline inflation since 2008 are explained primarily by price changes in one sector: energy. The down/up/down cycle in headline inflation coincides with a similar cycle in world oil prices. It appears that oil-price shocks have indirectly affected core inflation through their effects on headline inflation.

Researchers at the ECB have also found that oil-price shocks affect core inflation, and they offer an explanation (ECB Monthly Bulletin, 2014). The direct effects of large oil-price changes on headline inflation are filtered out of core inflation (regardless of whether core is measured by median inflation or by XFE inflation). But oil-price shocks affect costs and therefore prices in non-energy industries that use oil as an input. Core inflation responds over time as the effects of the shocks move through production chains.

There is another channel through which shocks to headline inflation can feed into core inflation: wage adjustment. This idea–focusing again on the effects of oil prices–appears in

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the classic work of Bruno and Sachs (1985) and in Peersman and Van Robays (2009). These authors suggest that nominal wages adjust to headline-inflation shocks, protecting workers' real wages from the shocks. Changes in nominal wages are then passed through, at least in part, to core inflation.

According to Bruno and Sachs and Peersman and Van Robays, the response of wages to headline inflation arises from features of European labor markets, including formal or informal indexation and labor unions with the strength to protect real wages. These authors suggest that wages respond less to inflation in the United States, because of different labor market institutions. We will return to this comparison when we discuss the U.S. Phillips curve.

An Augmented Phillips Curve

Based on the foregoing discussion, we add a new variable to the Phillips curve: $\pi^h - \pi$, the deviation of headline inflation (π^h) from core inflation (π). When core inflation is measured by weighted median inflation, $\pi^h - \pi$ captures large relative price changes that skew the distribution of industry inflation rates to the left or right, pushing headline inflation above or below the median.[4]

As we have discussed, many of the large price changes that affect $\pi^h - \pi$ occur in energy industries–but not all of them. Recall, for example, the large price changes for education and transport insurance in October 2017.

It presumably takes time for headline-inflation shocks to transmit to core inflation through the chain of production and wage adjustment. We therefore include lags of $\pi^h - \pi$ in our

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[4]The Phillips curve in Ball and Mankiw (1995) includes a different measure of large price changes that influence headline inflation. This variable is the total contribution to inflation of industries whose relative prices change by more than a cutoff of X percent (with X set to 10 or 25).

augmented Phillips curve. Our preferred specification is

$$\pi_t = \pi_t^e + \alpha\overline{(y - y^*)}_{t-1} + \beta\overline{(\pi^h - \pi)}_t + \epsilon_t, \tag{2}$$

where $\overline{(\pi^h - \pi)}_t$ is the average of $\pi^h - \pi$ from $t - 3$ through t.

We have also estimated a more general equation that allows different coefficients on the current $\pi^h - \pi$ and each of its three lags. The results are consistent with our preferred specification: the contemporaneous $\pi^h - \pi$ term is significant; the three lags are jointly significant; and we cannot reject the restriction that the four terms have equal coefficients, so only their average matters.

Estimates

The first two columns of Table 2 report estimates of equation (2) with core inflation measured by weighted median inflation. The output gap remains highly significant, and its coefficient is close to its coefficient in the basic Phillips curve (Table 1). The new $\overline{\pi^h - \pi}$ term is also highly significant, and including it raises the $\overline{R}^2$ from 0.64 to 0.76. When a constant term is included, it is insignificant.

The coefficient on $\overline{\pi^h - \pi}$ is 0.34: If four-quarter headline inflation exceeds core inflation by one percentage point, that difference raises current core inflation by about three tenths of a point.

The measurement of core inflation matters critically for these results. The last two columns of Table 2 report estimates of equation (2) with core measured by XFE inflation, both on the left side of the equation and in the $\overline{\pi^h - \pi}$ term on the right. In this case, the coefficient on $\overline{\pi^h - \pi}$ is insignificant ($t < 1.0$), and the coefficient has the wrong sign when there is no constant term.

Fitted Values for the Modified Phillips Curve

Figure 5 compares the path of median inflation to the fitted values from equation (2) with no constant (the first column of Table 2). We again present results for quarterly inflation and for four-quarter averages. We see that the fit of the equation improves markedly compared to the basic Phillips curve without $\overline{\pi^h - \pi}$. For four-quarter averages, the fitted values almost exactly match the fall in actual inflation from 2008Q3 to 2010Q2, and they come close to matching the rise in inflation from 2010Q3 to 2011Q4.

The recent missing-inflation puzzle does not disappear entirely, but it diminishes. For four-quarter averages, actual inflation falls persistently below the fitted values only in 2017Q2, compared to 2014Q3 for the basic Phillips curve. The gap between fitted and actual four-quarter inflation peaks at 0.29 points in 2017Q4. In the last quarter of the sample, 2018Q4, the fitted value is 1.80 and actual inflation is 1.52.

5   Comparison to the United States

We have developed a Phillips curve that captures the behavior of median inflation in the Euro area. Is this behavior specific to Europe, or does our specification also explain inflation in other economies? To address this question, we estimate this paper's Phillips curves for the United States, both the basic Phillips curve (equation (1)) and the version that includes headline-inflation shocks (equation (2)).

In this analysis, we measure core inflation with the weighted median CPI inflation rate published by the Federal Reserve Bank of Cleveland. As we did for Europe, we construct a four-quarter moving average of the output gap from annual OECD estimates of potential output. We measure expected inflation with ten-year forecasts from the U.S. Survey of Professional Forecasters. The sample period is 1986-2018, which is based on the availability of the potential output series.

Table 3 presents our Phillips-curve estimates for the U.S. For the basic Phillips curve (1), the results are similar to those for Europe. The output gap is highly significant, and when a constant term is included it is insignificant. The coefficients on the output gap are somewhat smaller than those for Europe (in the equation without a constant, the coefficient is 0.17 for the U.S. and 0.23 for Europe), but these differences are not statistically significant.

In contrast, when the $\pi^h - \pi$ term is added to the Phillips curve, the U.S. results diverge sharply from the European results. There is no evidence that the headline-inflation movements captured by $\pi^h - \pi$ push core inflation in the same direction. The estimated coefficients on $\overline{\pi^h - \pi}$ are statistically insignificant ($t < 0.4$) and they have the wrong sign (negative).

Recall that one motivation for including $\pi^h - \pi$ in the European Phillips curve is the idea that nominal wages respond to headline-inflation shocks. Bruno and Sachs and Peersman and Van Robays suggest that this aspect of wage behavior arises from labor-market institutions that exist in Europe but not the United States. This line of thinking might explain our findings that $\pi^h - \pi$ influences core inflation in Europe but not the U.S.

6   Conclusion

One theme of this paper is the measurement of core inflation. For the Euro area, as for the United States, we find that the weighted median inflation rate is a less volatile measure of core inflation, and one whose movements are easier to explain, than the inflation rate excluding food and energy prices. We hope that this research encourages students of European inflation to pay more attention to the weighted median.

We find that fluctuations in weighted median inflation in the Euro area are well explained by a simple Phillips curve. In this equation, median inflation is determined by expected inflation, the gap between actual and potential output, and the pass-through of headline-inflation shocks to core inflation.

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The most notable residuals in our equation appear in 2017-2018, the last two years of our sample. The equation modestly over-predicts the levels of median inflation in those years, which suggests there is some truth in the common perception of a "missing inflation." Going forward, we will see whether this anomaly persists, and we should seek to explain it.

Appendix: A Phillips Curve with Unemployment Gaps

Studies of the Phillips curve sometimes measure economic slack with the gap between output and potential output, and sometimes with the gap between unemployment and its natural rate. The main text of this paper uses the output gap and this Appendix uses the unemployment gap. The basic Phillips curve becomes:

$$\pi_t = \pi_t^e + \alpha \overline{(u - u^*)}_{t-1} + \epsilon_t, \tag{A1}$$

where $\overline{(u - u^*)}_{t-1}$ is the log difference between the averages of unemployment and its natural rate from $t - 1$ through $t - 4$.

We construct $\overline{(u - u^*)}$ from quarterly data on the unemployment rate and annual OECD estimates of the natural rate. Our method parallels our construction of four-quarter output gaps in our main analysis.

Table A1 presents estimates of the unemployment Phillips curve (A1), and of that equation augmented with our headline-inflation-shock variable $\overline{\pi^h - \pi_t}$. We omit constant terms (which are insignificant if we include them). Broadly, the results tell the same story as our output-gap Phillips curves. The coefficients on the unemployment gap are negative and highly significant, confirming the tradeoff between slack and inflation.

However, the equations do not fit the data as well as the output-gap Phillips curves. For the basic Phillips curve, the $\overline{R}^2$ falls from 0.64 to 0.53 when the output gap is replaced by the unemployment gap. When the $\overline{\pi^h - \pi}$ term is included, the $\overline{R}^2$ falls from 0.76 to 0.67.

Figure A1 shows four-quarter averages of actual median inflation and the fitted values from the unemployment Phillips curve with $\overline{\pi^h - \pi}$ included. We can compare this Figure to Figure 5B, which is the same except that slack is measured by the output gap. We see that the fit is worse with the unemployment gap in part because the fitted values for median inflation fall by less than the actual values over 2009Q1-2011Q2, after the global financial crisis. This pattern is the opposite of a missing disinflation.

These results reflect the fact that $\overline{(u - u^*)}$ does not rise much after the global crisis: it peaks at 0.4 percentage points in 2009Q4. This level is much lower than the level after the European debt crisis, when $\overline{(u - u^*)}$ rises to 3.0 points in 2013Q4. By contrast, the $\overline{(y - y^*)}$ series indicates almost as much slack after the first crisis as after the second. As a result, the Phillips curve with $\overline{(y - y^*)}$ can better explain the substantial fall in inflation in both episodes.

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Table 1: Euro Area Basic Phillips Curve, 1999Q1-2018Q4

$\pi_t = \pi_t^e + \alpha\overline{(y-y^*)}_{t-1} + \epsilon_t$				
	Median Inflation		XFE Inflation	
$Constant$		-0.052		-0.320
		(0.060)		(0.086)
α	0.228	0.221	0.238	0.194
	(0.024)	(0.025)	(0.037)	(0.031)
$\overline{R}^2$	0.643	0.646	0.207	0.459
$S.E.of Reg.$	0.345	0.343	0.540	0.447

Note: OLS with robust (HAC) standard errors is used (standard errors in parentheses). π_t is core inflation in quarter t, and π_t^e is the ECB's SPF mean point forecast of 5-year ahead inflation (1999Q2-4 and 2000Q2-Q4 are linearly interpolated due to missing data). $\overline{(y-y^*)}_{t-1}$ is the average output gap from $t-4$ through $t-1$ based on OECD estimates of potential output.

Table 2: Euro Area Phillips Curve with Price Shock, 1999Q1-2018Q4

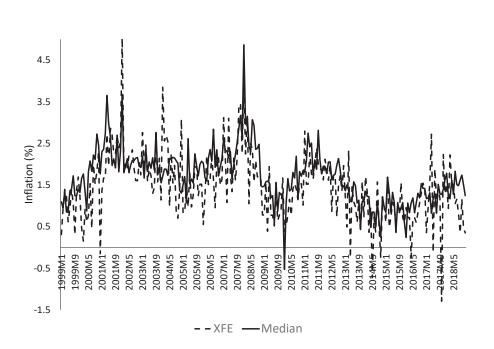| $\pi_t = \pi_t^e + \alpha\overline{(y-y^*)}_{t-1} + \beta\overline{(\pi^h - \pi)}_t + \epsilon_t$				
	Median Inflation		XFE Inflation	
$Constant$		-0.066		-0.356
		(0.047)		(0.100)
α	0.209	0.200	0.243	0.183
	(0.017)	(0.019)	(0.038)	(0.037)
β	0.341	0.349	-0.095	0.121
	(0.065)	(0.062)	(0.157)	(0.123)
$\overline{R}^2$	0.755	0.764	0.209	0.467
$S.E.of Reg.$	0.286	0.280	0.540	0.443

Note: OLS with robust (HAC) standard errors is used (standard errors in parentheses). π_t is core inflation in quarter t, π_t^h is headline inflation, and π_t^e is the ECB's SPF mean point forecast of 5-year ahead inflation (1999Q2-4 and 2000Q2-Q4 are linearly interpolated due to missing data). $\overline{(y-y^*)}_{t-1}$ is the average output gap from $t-4$ through $t-1$ based on OECD estimates of potential output. $\overline{(\pi^h - \pi)}_t$ is the average difference between headline and core inflation from $t-3$ through t.

Table 3: U.S. Phillips Curve, 1986Q1-2018Q4

$$\pi_t = \pi_t^e + \alpha\overline{(y - y^*)}_{t-1} + \beta\overline{(\pi^h - \pi)}_t + \epsilon_t$$

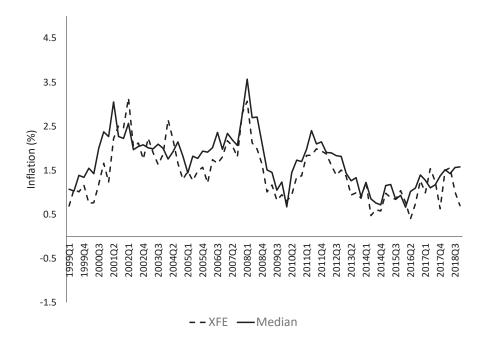|	Without Headline-Inflation Shocks		With Headline-Inflation Shocks	
$Constant$		0.040		0.036
		(0.065)		(0.065)
α	0.169	0.177	0.172	0.178
	(0.049)	(0.047)	(0.049)	(0.047)
β			-0.030	-0.026
			(0.080)	(0.080)
$\overline{R}^2$	0.665	0.664	0.664	0.662
$S.E.of Reg.$	0.506	0.507	0.507	0.508

Note: OLS with robust (HAC) standard errors is used (standard errors in parentheses). π_t is core inflation in quarter t, and π_t^e is the Philadelphia Fed's SPF mean point forecast of 10-year ahead inflation. $\overline{(y - y^*)}_{t-1}$ is the average output gap from $t - 4$ through $t - 1$ based on OECD estimates of potential output. $\overline{(\pi^h - \pi)}_t$ is the average difference between headline and core inflation from $t - 3$ through t.

Table A1: Euro Area Phillips Curve with Unemployment Gap, 1999Q1-2018Q4

$$\pi_t = \pi_t^e + \alpha\overline{(u - u^*)}_{t-1} + \beta\overline{(\pi^h - \pi)}_t + \epsilon_t$$

	Without Headline-Inflation Shocks	With Headline-Inflation Shocks
α	-0.312	-0.286
	(0.037)	(0.027)
β		0.378
		(0.083)
$\overline{R}^2$	0.527	0.666
$S.E.of Reg.$	0.397	0.333

Note: OLS with robust (HAC) standard errors is used (standard errors in parentheses). π_t is core inflation in quarter t, and π_t^e is the ECB's SPF mean point forecast of 5-year ahead inflation (1999Q2-4 and 2000Q2-Q4 are linearly interpolated due to missing data). $\overline{(u - u^*)}_{t-1}$ is the average unemployment gap from $t - 4$ through $t - 1$ based on OECD estimates of the equilibrium unemployment rate. $\overline{(\pi^h - \pi)}_t$ is the average difference between headline and core inflation from $t - 3$ through t.

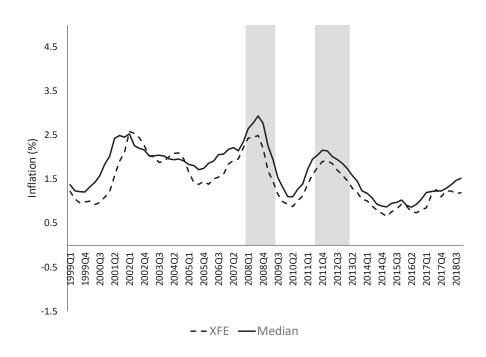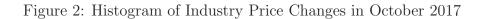Figure 1: Euro Area XFE and Median Inflation
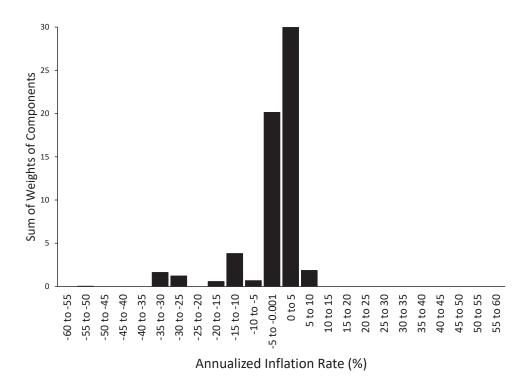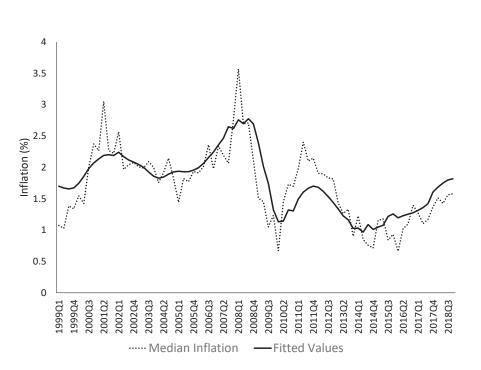
(a) Monthly

(b) Quarterly

(c) 4-Quarter Moving Average

Note: The grey bars are recessions as dated by CEPR.

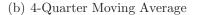Figure 2: Histogram of Industry Price Changes in October 2017

Note: The vertical axis is cut off at 30–the sum of industry weights in the 0 to 5% inflation range is 70. Food and energy industries are excluded.
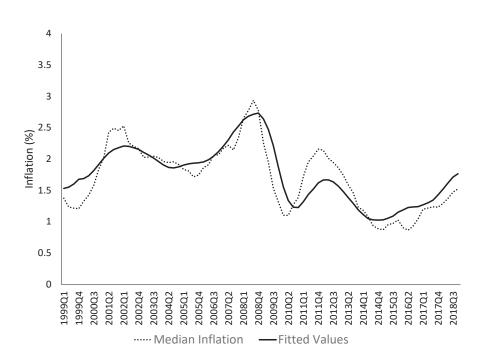
Figure 3: Actual and Fitted Values from Euro Area Basic Phillips Curve (Table 1, column 1)

(a) Quarterly

(b) 4-Quarter Moving Average

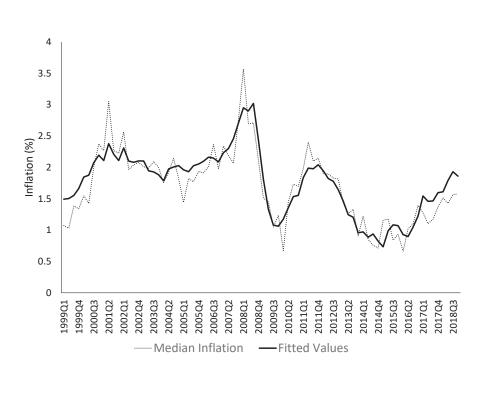Figure 4: Euro Area 4-Quarter Averages of Median Inflation, Fitted Values from Basic Phillips Curve, and Headline Inflation

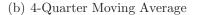Figure 5: Actual and Fitted Values from Euro Area Phillips Curve with Headline-Inflation Shock (Table 2, column 1)
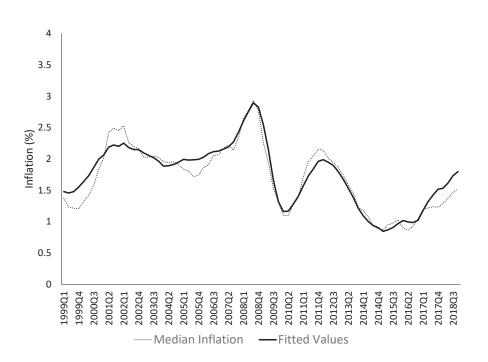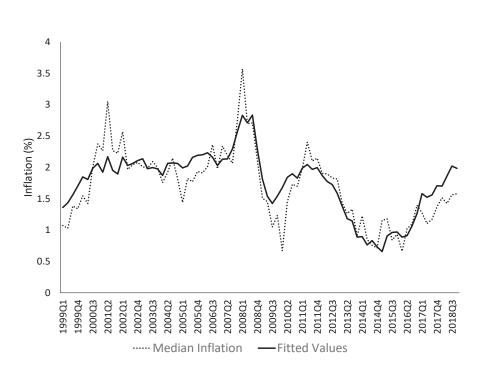
(a) Quarterly

(b) 4-Quarter Moving Average

Figure A1: Actual and Fitted Values from Euro Area Phillips Curve with Unemployment Gap and Headline-Inflation Shock

(a) Quarterly

(b) 4-Quarter Moving Average