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WEIGHTED MEDIAN INFLATION AROUND THE WORLD: A MEASURE OF CORE INFLATION

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ABSTRACT

The standard measure of core or underlying inflation is the inflation rate excluding food and energy prices. This paper constructs an alternative measure, the weighted median inflation rate, for 38 advanced and emerging economies using subclass level disaggregation of the CPI over 1990-2021, and compares the properties of this measure to those of standard core. For quarterly data, we find that the weighted median is less volatile than standard core, more closely related to economic slack, and more closely related to headline inflation over the next year. The weighted median also has a drawback: in most countries, it has a lower average level than headline inflation. We therefore also consider a measure of core inflation that eliminates this bias, which is based on the percentile of sectoral inflation rates that matches the sample average of headline CPI inflation.

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I. Introduction

Economists have long sought a good measure of the underlying or core inflation rate, one that filters out transitory fluctuations in headline inflation arising from sectoral shocks. Gordon (1975) proposed a simple measure of core: the inflation rate excluding the prices of food and energy. This definition was motivated by the experience of the 1970s, when large swings in food and energy prices were the main sources of volatility in headline inflation. In the last forty years, inflation excluding food and energy (XFE inflation) has become the standard measure of core inflation in the United States, and it has proven fairly successful in the sense that it is substantially less volatile than headline inflation. The Federal Reserve monitors and forecasts this version of core inflation, and policymakers often say they base their actions on its behavior (e.g., Mishkin, 2007).

Over the years, the use of XFE inflation as a measure of core has spread to central banks around the world. For the US, a consumer price index excluding food and energy was first reported by the Bureau of Labor Statistics (BLS) in the *CPI Detailed Report* for December 1975 and was regularly included from 1978 (Luciani and Trezzi, 2019). Other central banks, such as the Reserve Bank of New Zealand and the Reserve Bank of Australia, were also early adopters of XFE inflation (Cutler, 2001) with many more now publishing similar series.

Many researchers, however, have pointed out that volatility in headline inflation can arise from price changes in industries other than food and energy. For the United States, for example, Dolmas (2005) 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 2016).

This experience has led to the development of an alternative type of core-inflation measure: measures that exclude outliers in the distribution of industry price changes in a given period, regardless of which industries they are. These "outlier-exclusion" measures of core, which were developed largely at the Federal Reserve Banks of Cleveland and Dallas, include weighted medians and trimmed means of the distribution of industry inflation rates. They eliminate the effects of unusually large price changes in any industry, not just food and energy. Arguably the simplest version is the weighted median inflation rate, which is a limiting case in which 50% of the distribution is trimmed off each side and core inflation is measured by the industry inflation rate in the middle. This version of core inflation is the focus of this paper.[1]

A substantial literature has compared the properties of weighted median inflation and XFE inflation in the United States. One common finding is that the weighted median is less volatile. For example, for monthly CPI data over 1985-2019, Ball et al. (2021) report that the standard deviations of median and XFE inflation are 1.05 and 1.42 respectively. That paper also reports a big difference in volatility during the COVID pandemic: for January 2020-November 2021, the standard deviation of median was 1.51 while the standard deviation of XFE inflation ballooned to 3.86 due to sharp price swings in industries such as hotels, airlines, clothing, and used cars.

Economists and policymakers often argue that 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). Studies, which typically focus on the US, consistently find that the weighted median outperforms

[1] Pioneering work on outlier-exclusion core measures includes Bryan and Pike (1991) and Bryan and Cecchetti (1994).

XFE inflation by this criterion. For example, for 1985-2017 Ball and Mazumder (2020) estimate a simple Phillips curve in which quarterly core inflation is explained by detrended unemployment. They find that the adjusted R^2 is 0.48 when core is measured by the weighted median and only 0.22 when it is measured by XFE.[2]

Outside the United States, the Bank of Canada studied alternative core inflation measures as part of its five-year review of its policy framework in 2016. Consistent with research on the U.S., the Bank found that outlier-exclusion measures of core are less volatile and more closely related to economic slack than its official CPIX measure, which was similar to XFE inflation. This research led the Bank to replace the CPIX measure with a weighted median and trimmed mean. 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). The Reserve Bank of Australia has published trimmed mean and weighted median inflation since 2007 and uses these measures as estimates of underlying inflation (Richards and Rosewall, 2010). Interest in outlier-exclusion measures has grown during the COVID pandemic because of the extreme volatility of XFE inflation during that episode.

To date, outlier exclusion measures of core have been constructed for only a handful of countries. With the goal of promoting cross-country research, this paper constructs a weighted-median measure of core inflation for 38 countries, including both advanced and emerging market economies. Specifically, we compute quarterly series based on data from Haver Analytics on industry inflation rates at the fourth or "subclass" level of disaggregation, which typically includes between 150 and 250 industries for each country, for time periods that extend from the 1990s to the present for many countries. We also study the properties of these core measures and compare them to the standard XFE measure. For completeness monthly analysis is also conducted and can be found in the Appendix.

We find that the attractive properties of median inflation in U.S. and Canadian data largely extend to our wider group of countries, albeit with some variation across countries. Weighted median is usually somewhat less volatile than the standard core measure at the quarterly frequency and much less volatile at the monthly frequency. We also find that the relationship between core inflation and economic slack, as measured by the fit of a simple Phillips curve based on quarterly data, is clearer for most countries when core is measured by the weighted median. Finally, the current level of median inflation is a better predictor of headline inflation over the next twelve months than is standard core, with the results the strongest when we examine current monthly levels of the core measures.

We also find a shortcoming of the weighted median. The weighted median is a biased estimator of core inflation in the sense that its average level over time is lower than that of headline inflation. This feature, which is particularly prevalent for many countries at the monthly frequency, reflects the fact that disaggregated inflation rates can often be zero, meaning that the measured price in an industry does not change. Motivated by this issue, we compute an adjusted measure of core inflation: the inflation rate at a sectoral percentile different from 50% defined by the condition that its average value over our sample equals that of headline inflation. For quarterly data, this percentile ranges from 50% to 60% for most countries. This measure eliminates the bias in the weighted median by construction, and it retains the desirable properties of low volatility and comovement

[2] Other work comparing median and XFE inflation in the United States includes Marques et al. (2003), Smith (2004), Crone et al. (2013), and Verbrugge (2021), among others.

with economic slack. However, its construction is sample-dependent given that it depends on matching the sample mean of headline inflation.

II. Data and Methodology

Data

The aim of the paper is to assess the performance of our weighted median inflation series across countries by comparing its properties to those of headline inflation and the standard measure of core inflation. In order to do so, we need data on headline inflation, standard core, an inflation breakdown at the sectoral level for computing the weighted median, and key variables for our Phillips curve. Our data are an unbalanced panel that spans 38 countries, which include both advanced and emerging market economies.

Our measure of headline inflation is the all-items Consumer Price Index (CPI) that is typically reported by a country's central bank or statistical agency. The standard core measure is headline inflation excluding food and energy prices, also known as core XFE. [3] The weighted median inflation series for each country is constructed for each period 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. We examine sectoral inflation rates at the fourth level of disaggregation of headline CPI, or about 150 to 250 sectors per country. Inflation data spans from 1990 to 2021, with somewhat unbalanced availability by country, and is from Haver Analytics.

To estimate a Phillips curve at the quarterly frequency for each country, we use GDP data from Haver Analytics. Two-year and five-year ahead inflation expectations are from the quarterly Consensus Forecasts dataset, and for robustness we also use five-year ahead expectations from the IMF's World Economic Outlook database. Data on GDP and inflation expectations span from 1990 to 2021, dependent on country availability.

Table 1. Country Sample

Advanced Economy		
Austria	Hong Kong	Slovenia
Belgium	Ireland	South Korea
Canada	Italy	Spain
Czech Republic	Japan	Sweden
Denmark	Latvia	Switzerland
Estonia	Lithuania	United Kingdom
Finland	Netherlands	United States
France	Norway	
Germany	Portugal	
Greece	Slovakia	

Emerging Markets	
Brazil	Romania
Bulgaria	
Chile	
Costa Rica	
Croatia	
Hungary	
Malaysia	
Mexico	
Peru	
Poland	

[3] Measures of core inflation in some countries exclude administered prices.

Measuring Median Inflation at Different Frequencies

We compute inflation at three different frequencies, monthly, quarterly, and annual, following Ball and Mazumder (2020).

For each country, our industry-level data are monthly series for the price level in each industry along with the industry weights. To compute median inflation at the monthly frequency, we compute each industry's inflation rate from month t-1 to month t and take the weighted median of the distribution of inflation rates. We annualize our series by multiplying monthly median inflation rates by 12.[4]

To compute median inflation at the quarterly frequency, we first construct a quarterly series for each industry's price level by averaging the industry price over the three months of a quarter. To compute the weighted median inflation rate for quarter t, we use each industry's price levels in quarters t-1 and t to compute an inflation rate for quarter t and again take the median of the industry inflation rates. Note that the quarterly median inflation rate is not an aggregate of the monthly rates defined above, because the distributions of industry price changes can differ at monthly and quarterly frequencies. (For example, suppose an industry has a large price change in a certain month but small price changes in the other two months of the quarter. This creates an outlier i n the distribution of monthly inflation rates but less of an outlier in the quarterly rates, so median inflation differs more from headline inflation at the monthly than at the quarterly frequency.) We annualize our quarterly median inflation rates by multiplying by four.[5]

Finally, for each month we compute a measure of median inflation over the previous 12 months. We do so by computing each industry's inflation rate from month t-12 to month t and taking the weighted median of the industry rates. Therefore, weighted median inflation can be defined for a particular country (j) at time t considering all industries (i) by using a ranking operator $\mathcal{R}_{i,j,t}$, which ranks the industry specific inflation rates ($\pi_{i,j,t}$) from smallest to largest and sums their corresponding weights (w). The weighted median inflation rate is selected as the inflation rate at time t for the industry *i* at which the sum of the ranked weights are at, or closest to from above, the 50th percentile; this is summarized in a stylized manner as follows:

$$\pi_{j,t}^{m} = \pi_{i,j,t} \text{ for industry } i \text{ such that } \mathcal{R}_{i,j,t} = 0.5,$$

where ranking operator $\mathcal{R}_{i,j,t}$ is defined as:

$$\mathcal{R}_{i,j,t} = \sum_{i'} w_{i',j,t} \text{ for } \pi_{i',j,t} \leq \pi_{i,j,t} \,.$$

The industry-level price data are not seasonally adjusted. After computing unadjusted monthly and quarterly inflation rates, we perform seasonal adjustment with the U.S. Census Bureau's X-11 version of the X-13ARIMA-SEATS program, which applies a sequence of moving average and smoothing calculations to estimate the trend-cycle, seasonal, and irregular components of a series. When we examine headline and standard core inflation rates, we use the same seasonal adjustment procedure.

Comparing Inflation Series

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[4] One may also use compounding to annualize.

[5] Quarterly median inflation rates are sometimes constructed differently. For example, the Federal Reserve Bank of Cleveland calculates an inflation rate over three months by averaging the three monthly rate s.

Throughout the paper, we compare the properties of headline, standard core, and weighted median inflation. Our first step is simply to compare the average levels and volatility of the different inflation measures in each country, for both monthly and quarterly data.

Our second step is to compare the performance of headline, standard core, and median inflation in terms of the fit of a Phillips curve, defined as the relationship between inflation, real activity and expectations of future inflation, at the quarterly frequency. Our baseline specification of the Phillips curve, following Ball and Mazumder (2020), is

$$\pi_t = \alpha + \pi_t^e + \beta y_t + \varepsilon_t ,$$

where π_t^e is five-year ahead inflation expectations and y_t is the output gap measured with seasonally adjusted real GDP detrended with the Hodrick-Prescott filter (λ=1600). We estimate the Phillips curve separately for each country, via OLS with heteroscedasticity and autocorrelation consistent standard errors[6] (Newey & West 1987, Andrews 1991). For robustness, in Appendix B we consider a hybrid Phillips curve that includes lagged inflation as well as expected inflation with unconstrained coefficients; we also estimate the Phillips curve in panel data with country fixed effects.

Our third step is to examine how well different inflation measures capture the one-year-ahead headline inflation. We do so with simple exercises in which we examine the performance of current headline, standard core, and median inflation as forecasters of future headline inflation. In all our exercises, future headline inflation for month t is measured over twelve months, from t to t+12. We compare the forecasting performance of current monthly, quarterly, and year-over-year levels of the three alternative inflation measures, as measured by root mean squared error (RMSE).

III. Results

This section presents the main results from our comparisons of headline, standard core, and weighted median inflation. We focus primarily on inflation at the quarterly frequency; results for the monthly frequency are presented in Appendix A.

A. Volatility

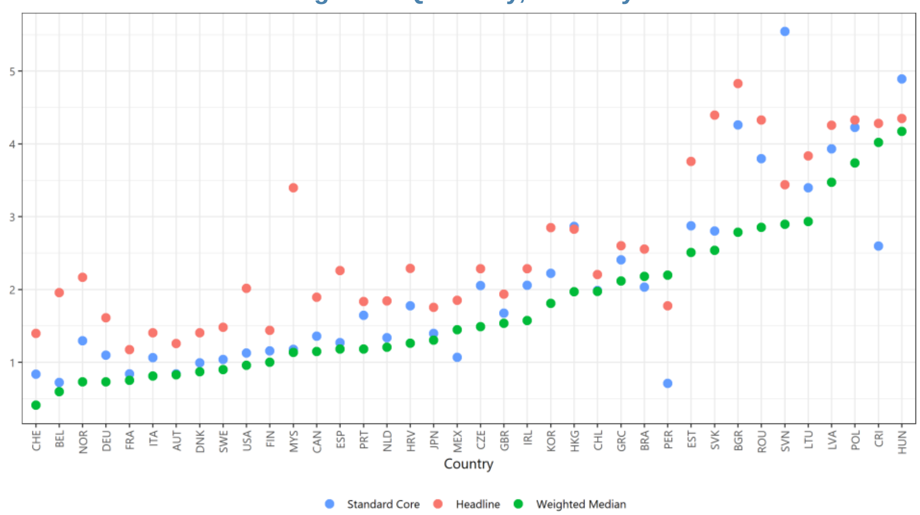
All else being equal, a good core measure minimizes volatility while still following the medium-term trend in headline inflation, as it picks up fewer temporary fluctuations in inflation. Hence, in Figure 1 we compare the sample variances of quarterly headline inflation (red), standard core inflation (blue) and weighted median inflation (green) for each of the 38 countries in our data set. The countries are ordered based on the variance of median to aid comparison of that core measure to the other series.

We find that the volatility of weighted median inflation is lower than the volatility of both headline and standard core inflation for most countries, consistent with previous evidence on the United States and Canada. This finding holds for quarterly inflation as shown in Figure 1, and holds especially strongly for monthly inflation (see Figure 14 in Appendix A). The result is particularly strong for advanced economies; for emerging economies the results are more mixed, with the volatility of weighted median close to or higher than that of standard core

[6] Heteroskedasticity and autocorrelation consistent standard errors are computed using the R function *vcovHAC,* which uses by default the vector of weights from Andrews (1991). For further detail see Zeileis (2004, 2006).

in Brazil, Costa Rica, Mexico and Peru.[7] We get broadly similar results if we measure volatility by the variance of the *change* rather than level of inflation, as shown in Appendix B.

Figure 1. Quarterly, Volatility



Source: Authors' calculations

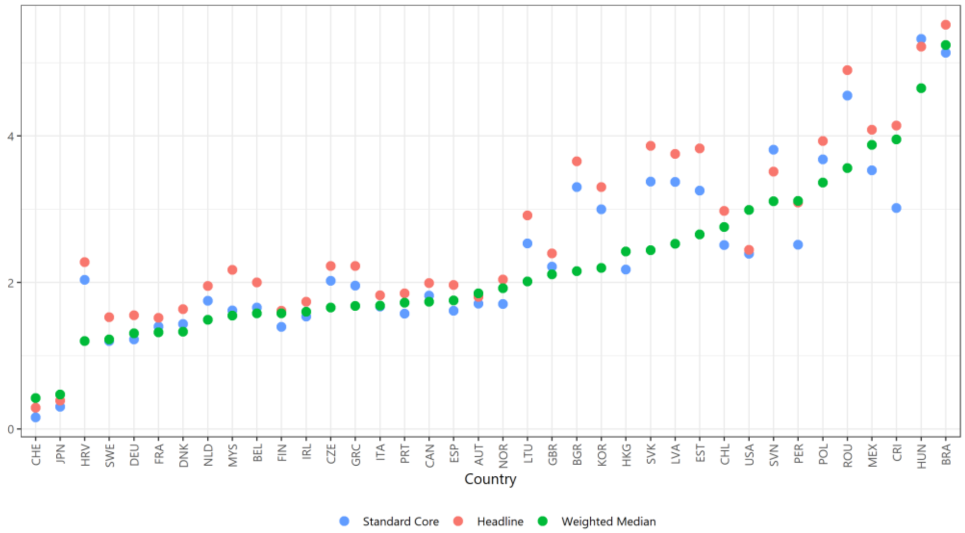
B. Average Inflation

To complement the analysis of volatility it is important to examine the means of the inflation measures, since the lower volatility of the weighted median could be driven in part by having a lower mean. When comparing, for each country, the sample means of the various inflation measures, we find that both the standard core and the weighted median inflation measures have a lower mean level than headline inflation. This result means that the two measures of core understate headline inflation on average, a fact that we call a "bias" in the core measures.

Figure 2 shows the average levels of the three inflation measures for each country. To help us see the negative bias in the core inflation measures, Figure 3 shows the deviations of their average levels from the average level of headline inflation. The negative bias is sometimes larger for standard core and sometimes for the weighted median. We see on the left side of Figure 3 that there is a group of eight countries (mostly emerging economies) for which the negative bias in the weighted median is considerably larger. The bias of median inflation is much larger at the monthly frequency, a finding explained in part by the frequency of zeros in monthly industry inflation rates (see Figure 16-17 in Appendix A and Annex C for a discussion of the relation between the inflation bias and share of observations with zero price changes). Note that the US is an outlier in our sample of countries, since the weighted median shows a positive rather than negative bias relative to headline inflation.

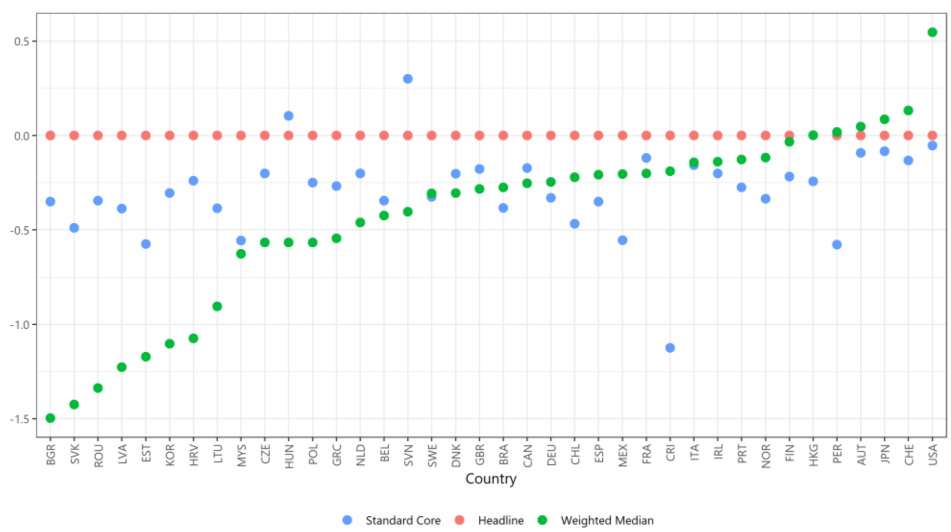
[7] This result deserves further explanation and analysis, which are outside the scope of this paper.

Figure 2. Quarterly, Mean



Source: Authors' calculations

Figure 3. Quarterly, Bias to Headline



Source: Authors' calculations

Bias relative to headline inflation is arguably an undesirable property for a measure of core inflation. Hence, in Section III.D below, we address this problem by introducing a new measure of core inflation, called P*, which minimizes bias by measuring core based on the percentile of sectoral inflation rates that matches the sample average of overall CPI inflation.

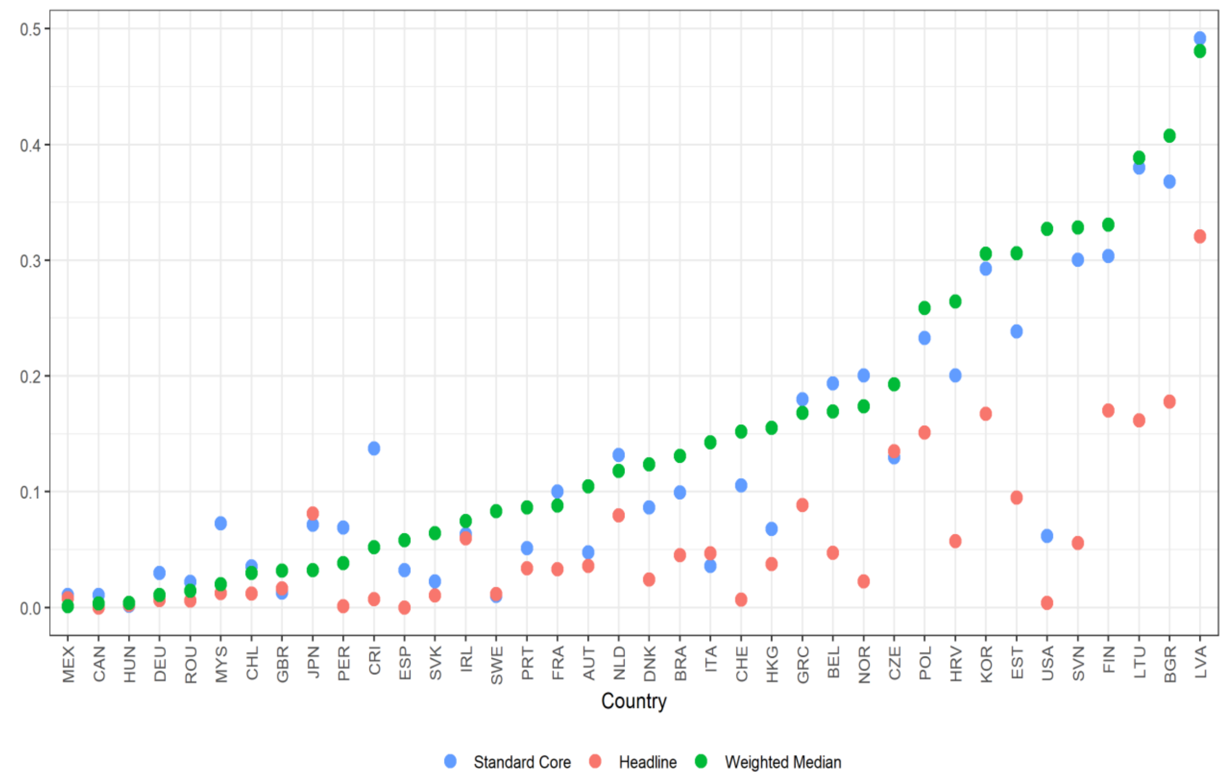
C. Phillips Curve Estimation

We now turn to assessing the performance of our inflation measures by estimating the Phillips curve presented in Section 2, in which inflation depends on expected inflation and the output gap. The estimations are done at the quarterly frequency due to the availability of GDP data. We judge the success of a specification by the goodness-of-fit statistic R-squared; a high R-squared means that the inflation measure on the left side of the equation is well-explained by the level of economic slack, which is a desirable property of a core inflation measure. The results from additional Phillips curve specifications are reported in Appendix B. Additionally, Appendix D reports the estimated output coefficients for each country, the difference in R^2 from the baseline specification using headline inflation, and the relation between $R^2$and the output gap coefficient, for our four key measures of inflation.

Figure 4 shows the R-squared of the Phillips curve for each country and each inflation measure. We see that the R^2 is highest for median inflation (green dots) for about three quarters of our countries, often by a substantial margin. For the other countries the R^2 is higher for standard core inflation but usually by only a small amount, so all in all the performance of the weighted median is better.

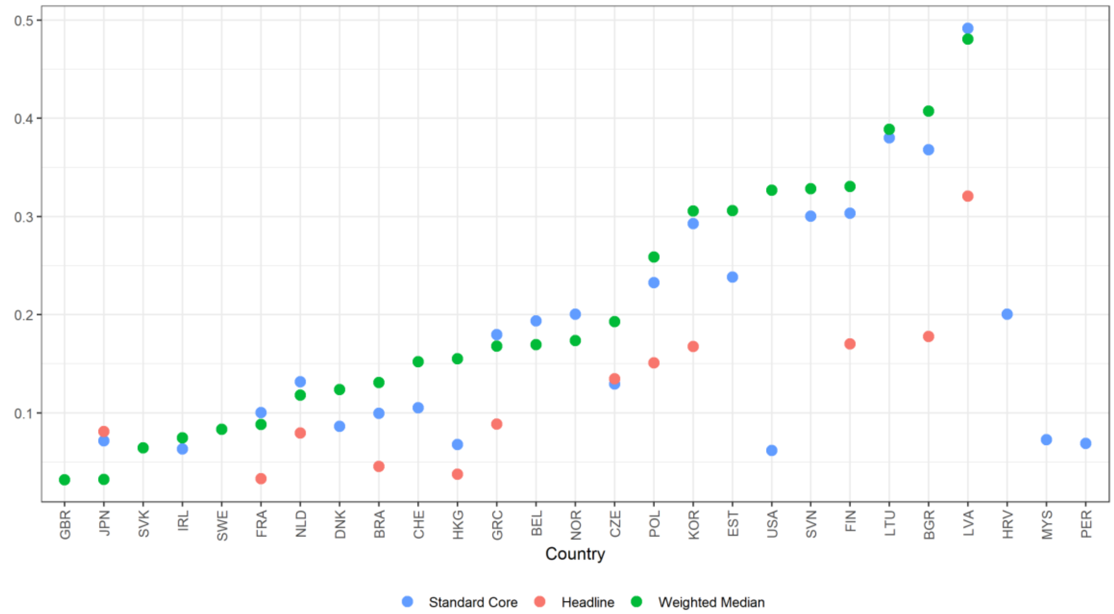
Our results are robust to alternative specifications. We find that the weighted median core measure performs well in terms of R^2 when we restrict the sample to countries where the coefficient on the output gap is positive and significant (Figure 5). The weighted median also performs well when inflation expectations are measured by 5-year ahead inflation expectations from the World Economic Outlook instead of our benchmark measure from Consensus Forecasts, and when we estimate a hybrid Phillips curve specification (with both forward and backward-looking inflation; see Figure 23 in Appendix B).

Figure 4. Phillips Curve, Baseline Specification, R^2



Source: Authors' calculations

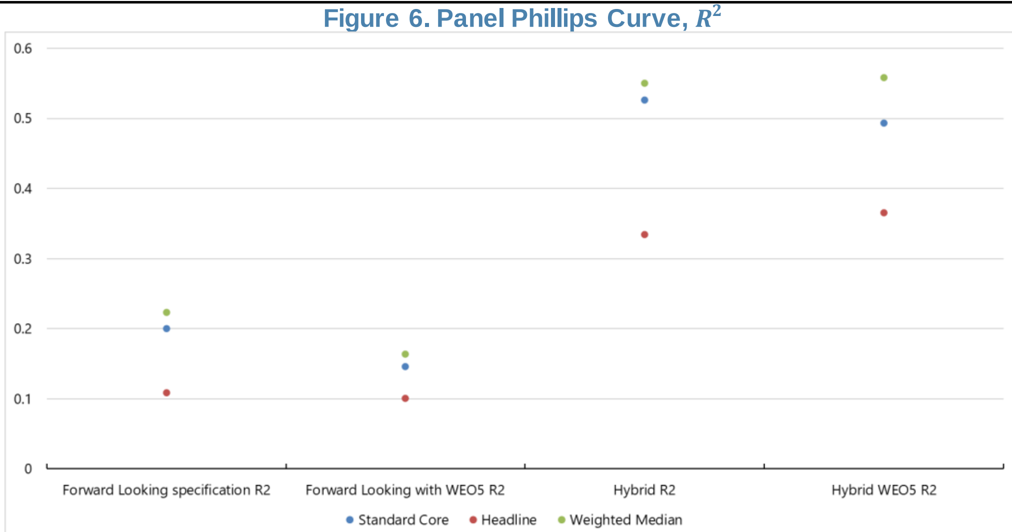
Figure 5. Phillips Curve, Baseline Specification, R^2, Showing Only Cases with Positive and Significant Coefficients on Output



Source: Authors' calculations

To further analyze the performance of the inflation measures, we pool the data for the countries in our sample and estimate Phillips curves with panel regressions that include country fixed effects. This specification assumes that the output coefficient in the Phillips curve is the same for all countries. Figure 6 shows the R^2 for the three inflation measures for our baseline Phillips curve and also for the hybrid Phillips curve, as well as—for both cases—with expectations measured with World Economic Outlook forecasts. In all cases the R^2 is highest with median inflation on the left side of the Phillips curve.

Figure 6. Panel Phillips Curve, R^2



Source: Authors' calculations

D. P*, An Unbiased Core Measure

Here we introduce a new core inflation measure that minimizes the bias relative to headline inflation that arises for the median measure of core, as seen in Section III.B. The new measure, which we call P*, is defined for each country as the inflation rate at the percentile of the sectoral inflation distribution with the smallest average difference between its level and that of headline inflation. For a given country j, the P* inflation is derived as the inflation rate π of the industry (*i*) associated with the percentile p_j of the sectoral inflation distribution that minimizes the average inflation bias versus headline (*h*) inflation over the sample *T, i.e.* that minimizes the following gap:

$$\min_{\mathrm{p_j}} \frac{1}{T}\sum \pi_{jt}^{h} - \frac{1}{T}\sum \pi_{jt}^{p^*} \quad \text{where } \pi_{jt}^{p^*} = \pi_{i,j,t} \;\text{ for industry } i \text{ such that } \mathcal{R}_{i,j,t} = p_j$$

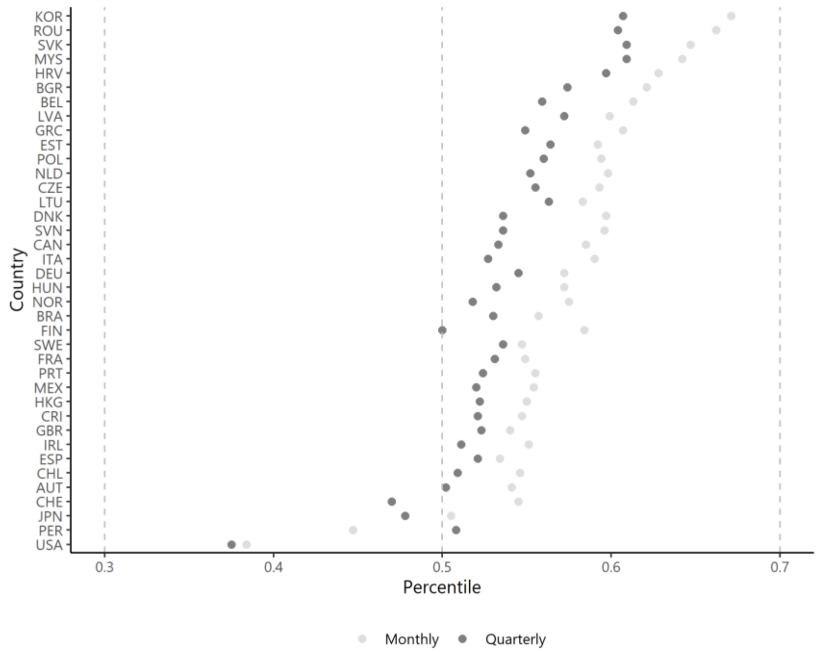
where the ranking operator $\mathcal{R}_{i,j,t}$ is defined as above:

$$\mathcal{R}_{i,j,t} = \sum_{i'} w_{i',j,t} \text{ for } \pi_{i',j,t} \leq \pi_{i,j,t} \, .$$

We find that the percentile p_j that minimizes the bias is above the median (or 50th percentile) for most countries and usually between the 50th and the 60th percentile for inflation at the quarterly frequency. It makes sense that a percentile above the 50th is generally needed to reduce bias, given that core as measured by the weighted median displays negative bias for most countries.[8] Given that, as discussed in the previous section, the US was an exception in this respect, with a positive inflation bias for the median, the percentile that minimizes bias for the US is below the 50th percentile, actually slightly below the 40th percentile. Note that the industry whose inflation rate is at the percentile associated with P* changes every month, just like the industry at the median of the distribution. One caveat of the P* measure is that the percentile of the distribution that defines P* differs across countries and across data frequencies (monthly, quarterly, and year-on-year), and it is also dependent on the sample period.

[8] A similar result is shown for Brazil by the *Banco Central do Brasil* and motivates their use of P55, the 55th percentile of the distribution weighted by the subitem weights (Banco Central do Brasil, June 2020 Inflation Report).

Figure 7. Percentile Associated with P*



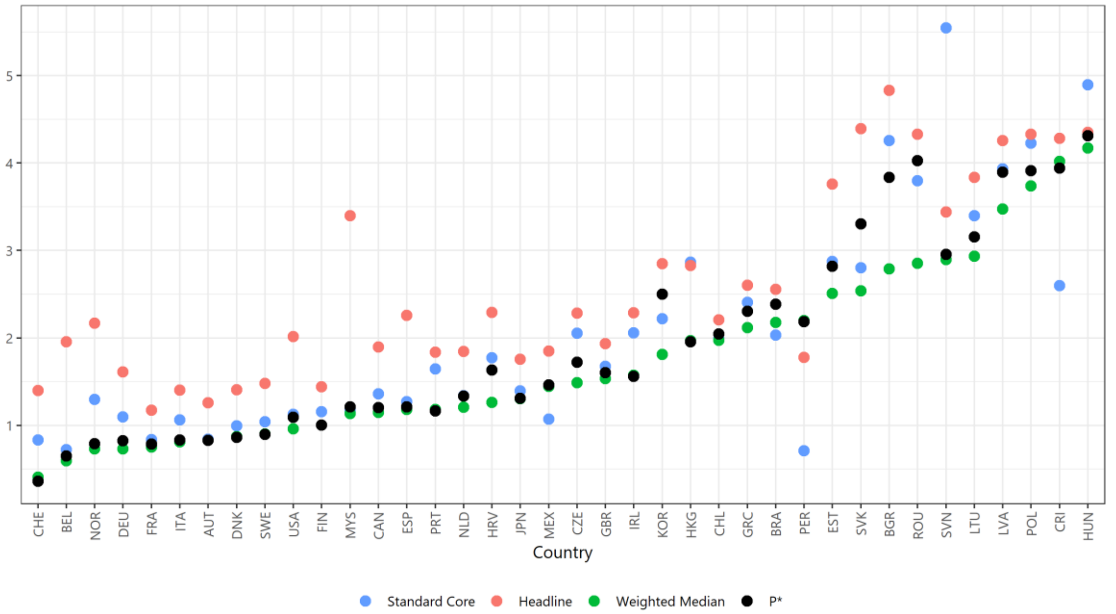
Source: Authors' calculations

We next compare the volatility, bias, and Phillips curve fit of our P* measure of core inflation to the weighted median, headline and standard core inflation.

E. P*: Results for Volatility and Bias

Figure 8 adds P* to Figure 1 on the variance of alternative inflation measures. We see that, for most countries, the volatility of P* is close to the volatility of the weighted median, and lower than the volatility of headline inflation and standard core. Thus, moving from median to P* as a measure of core fixes the problem of bias without sacrificing much in the stability of the core measure. There are, however, two countries (Korea and Slovakia) in which P* performs less well: median is less volatile than standard core but P* is more volatile than standard core. The generally good performance of P* carries over to monthly inflation data (see Appendix A, Figure 18).

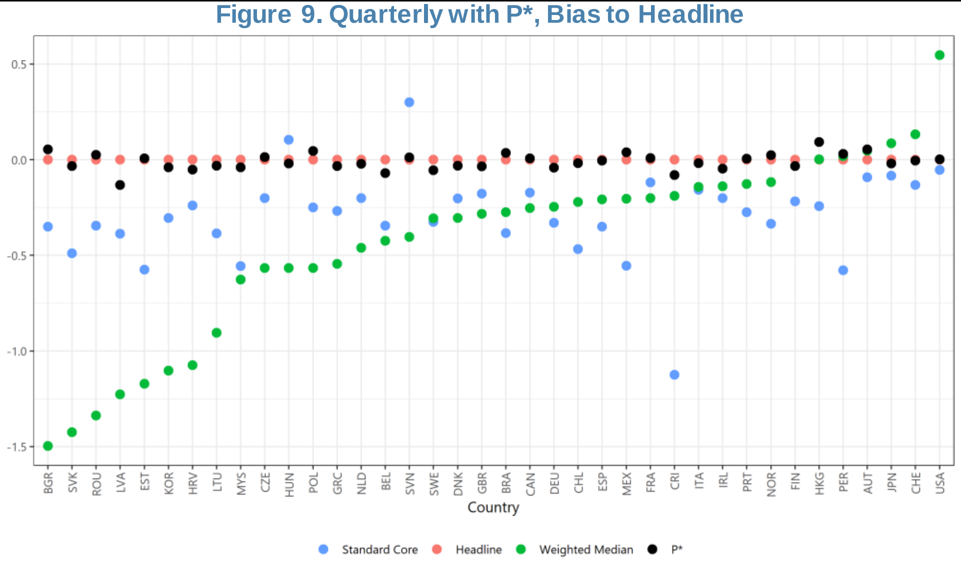
Figure 8. Quarterly with P*, Volatility



Source: Authors' calculations

Figure 9 repeats Figure 3 on the bias of alternative core measures, adding P* (black dots) along with median and standard core. By construction the bias relative to headline, which is derived by subtracting the mean of headline inflation from the mean of the other inflation measures, is minimized for P*. Due to a finite number of inflation series per country it is not possible to eliminate the bias completely, so the black dots are close but not identical to the red dots indicating zero bias.

Figure 9. Quarterly with P*, Bias to Headline

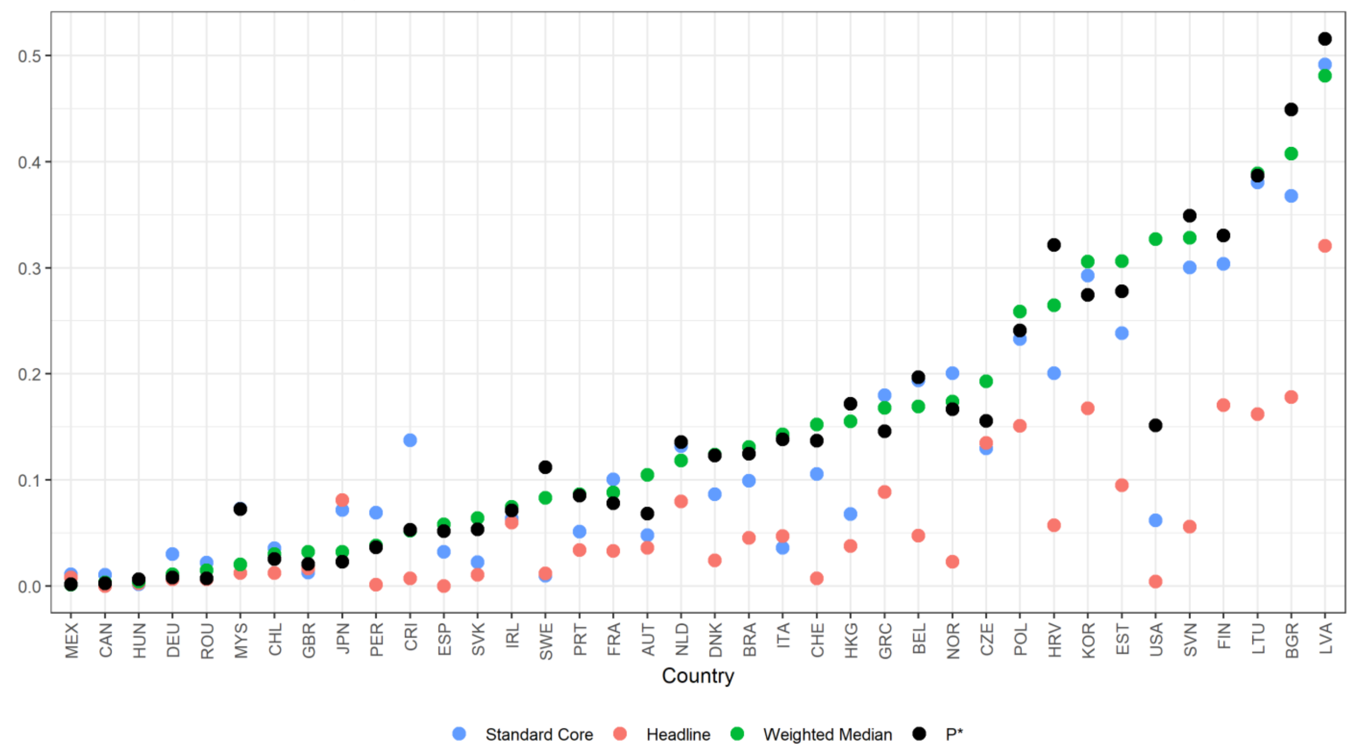


Source: Authors' calculations

F. P*: Results for Phillips Curves

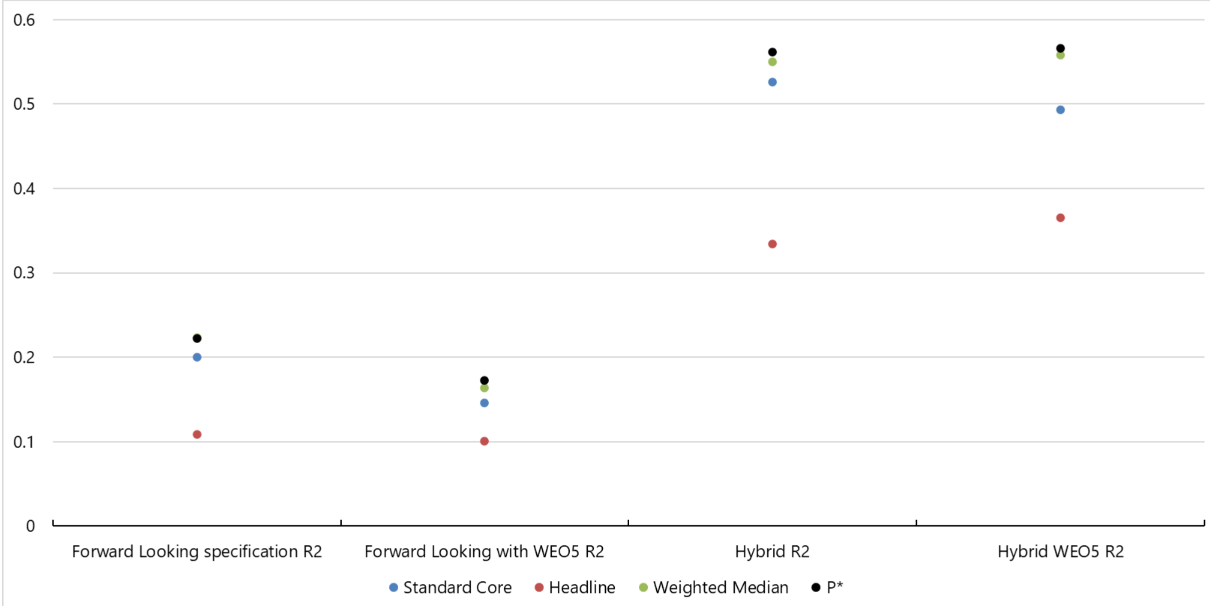
Our P* inflation measure also performs well in terms of fit of the Phillips curve. This is visible in both Figure 10, for our baseline country-specific Phillips curve, and Figure 11, for the panel estimation of alternative Phillips curve specifications. The R^2 for the Phillips curve with core inflation measured by P* (black dots) is generally close to the R^2 for median inflation (green dots); it is even noticeably higher for several countries. Like median inflation, P* outperforms both headline and standard core inflation for about three quarters of the countries in our sample, and in our panel regressions. A higher R^2 in the Phillips curve regressions when inflation is measured by the weighted median or P* signifies that more of the variance of inflation can be explained by domestic economic slack (see Annex D for the relation between the coefficient of the output gap and R^2 across inflation measures).

Figure 10. Phillips Curve, Baseline Specification with P*, R^2



Source: Authors' calculations

Figure 11. Panel Phillips Curve with P*, R^2



Source: Authors' calculations

G. Median and P*: Capturing One-Year-Ahead Headline Inflation

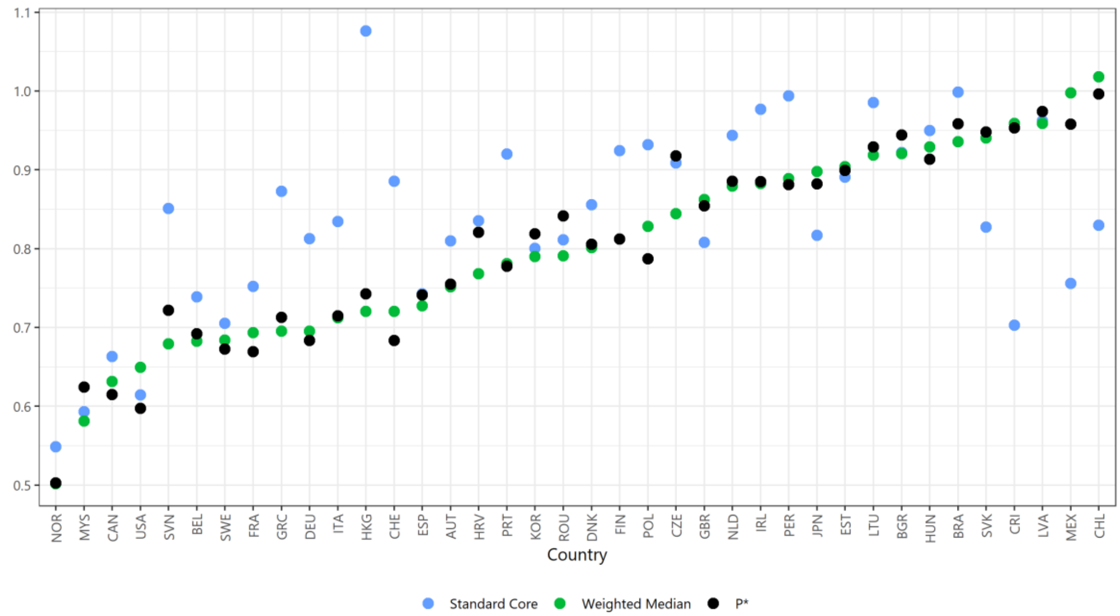
A good measure of core inflation is a good predictor of future headline inflation. Here we focus on headline inflation rate over the following twelve months, and we see how well this variable is predicted by the current quarterly levels of standard core, median, and P* inflation. For each of the core measures, we calculate the standard deviation of the difference between the one-year-ahead headline inflation and the core measure, and divide this statistic by the standard deviation of the difference between the one-year-ahead headline inflation and current headline inflation. If this ratio is less than one, then the quarterly core measure is a better predictor of the trend in headline inflation than is quarterly headline inflation itself.[9] [10]

Figure 12 presents the results. We see that the ratio we calculate is almost always less than one, indicating that all three core inflation measures are better measures of one-year-ahead headline inflation than is headline itself. For most countries, the ratio is lower for the weighted median than for standard core, suggesting again that the weighted median is a good core measure. Perhaps surprisingly, P* usually performs worse than the weighted median; correcting the bias in the median appears to be counterproductive here. As shown in Appendixes A and B, the performance of the weighted median as a measure of future headline inflation is even stronger when we examine the current monthly level of alternative core measures, but the results are inconclusive when we consider 12-month measures of core (see Figures 20 and 27).

[9] We perform this exercise at the monthly frequency. For each month t, we compute "quarterly" inflation rates at the industry level as the percentage change from the average price at t-5, t-4, and t-3 to the average price at t-2, t-1, and t. Headline and standard core inflation rates are also computed from average prices from t-5 through t-3 and from t-2 through t.

[10] This is not an exercise to determine the best metric to forecast headline inflation, which would require further testing using a variety of econometric models.

Figure 12. Quarterly, RMSE of Core Measures / RMSE of Headline Inflation



Source: Authors' calculations

H. 2021-22 Inflation Event

Given the large attention to inflation in recent years, it is interesting to see whether median inflation (and P*) were able to capture the increase in inflation ahead of standard core.

We offer simple illustrative evidence by graphing over time the distribution of 12-month inflation rates across our sample of countries, for each measure of inflation: headline, standard core, weighted median and P* (Figure 13). In particular, we show the 10th, 25th, 50th, 75th and 90th percentile of the country inflation rates in each month since 2019.

It appears that for all countries the weighted median and P* measures started capturing the increase in inflation almost immediately in 2021. However, when focusing on the red circles one can see that, for low inflation countries (the low percentiles of the distribution with pre-2020 inflation levels of less than 2.5%) the standard core inflation measure failed to capture the pickup in inflation as early as the weighted median or P*. For instance, the 10th percentile of the 12-month weighted median inflation started to consistently increase from March 2021, where it took standard core until August 2021.

Figure 13. 12-Month, Selected Country Percentiles

Source: Authors' calculations

IV. Conclusions

This paper examines the properties of alternative measures of core or underlying inflation in 38 countries. We focus on a comparison of the standard measure of core--the inflation rate excluding food and energy prices—to two alternative measures: the weighted median inflation rate and a new measure P*, the inflation rate at the percentile of the sectoral inflation distribution defined by the condition that its average value over our sample approximately equals that of headline inflation, hence minimizing the average sample bias relative to headline inflation.

Median inflation is less volatile than standard core inflation and produces a higher R^2 in a forward-looking Phillips curve. The median is a biased measure of core inflation: in most countries, its average level over time is lower than that of headline inflation. However, the standard core measure is also biased, and at the quarterly frequency its bias is sometimes larger and sometimes smaller than that of the median. All in all, the weighted median has better properties as a core inflation measure in most countries.

The P* measure of core has the desirable property that it minimizes bias relative to headline inflation, and it performs almost as well as the median in terms of low volatility and good fit of the Phillips curve. A caveat, however, is that the percentile of the industry inflation distribution associated with P* is sample-dependent.

Overall, this paper shows the limitations of the standard ex-food-and-energy measure of core inflation and the promise of alternative measures. We believe that policymakers and practitioners should pay more attention to outlier-exclusion core measures such as weighted median inflation and P*. These additional measures of underlying inflation should be considered when assessing the short-run policy trade-off implied by the Phillips curve and monetary policy reaction. While developing a theoretical underpinning is beyond the scope of this paper, future work would be welcome in this respect. Finally, researchers should continue to seek improvements in the measurement of core inflation.

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Appendixes

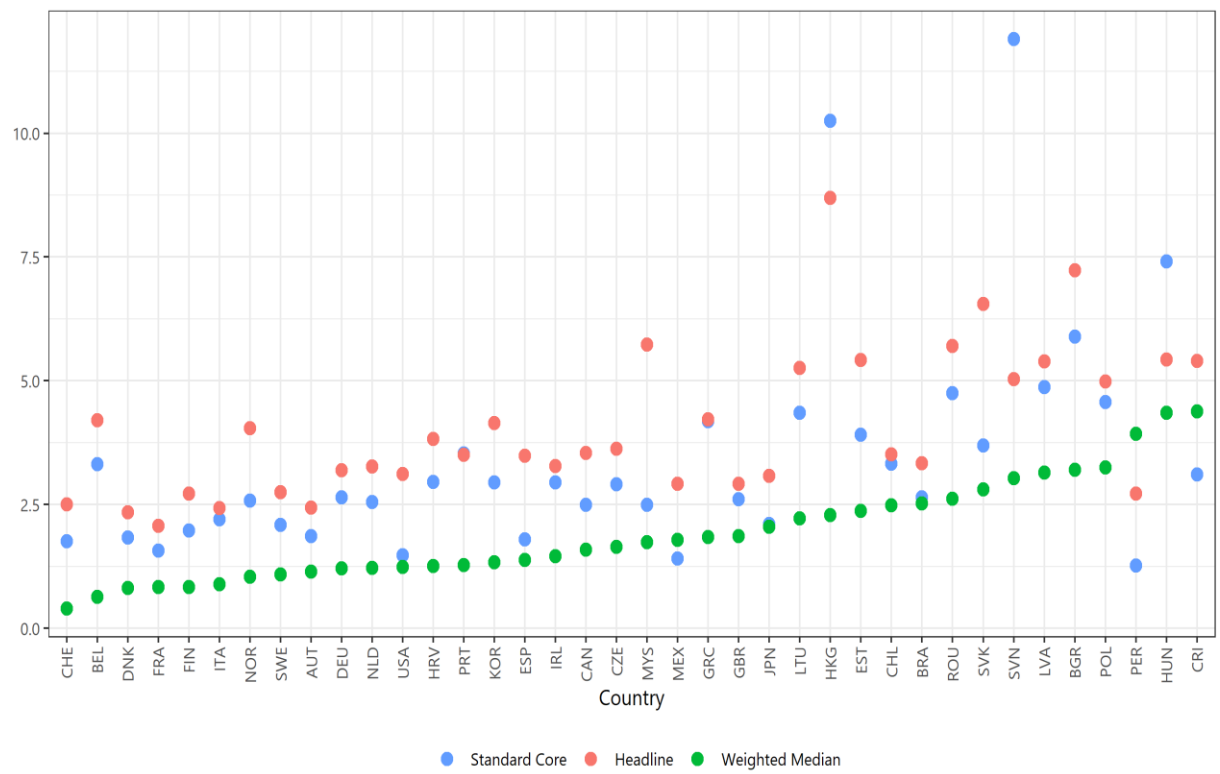
A. Monthly Results

This section houses the results for the monthly inflation metric. The layout follows the quarterly figures shown in the main body of the paper. The monthly and quarterly results are comparable, however the weighted median bias compared to headline inflation is more prominent.

A.1 Results on Volatility

Outlined below in Figure 14 is the volatility across countries for the headline (red), standard core (blue) and weighted median (green) inflation measure using our monthly inflation metric. Similarly, to the quarterly results we find that the volatility of the weighted median inflation s below that of standard core and headline for the majority of the countries in our sample. Where we see standard core outperform the weighted median is for some of the emerging market economic, such as Mexico, Peru and Costa Rica.

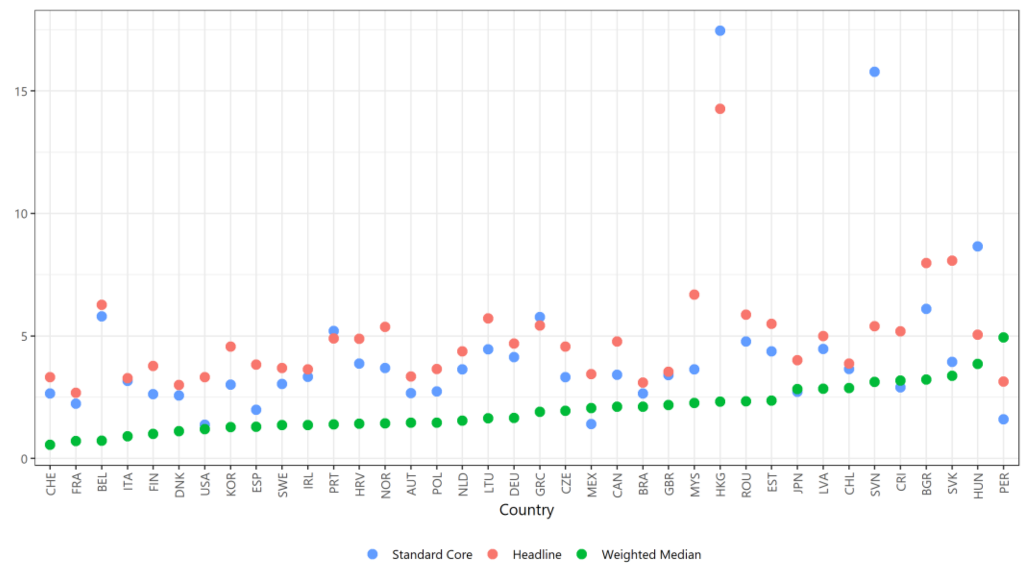
Figure 14. Monthly, Volatility



Source: Authors' calculations

These results hold if we look instead at the volatility of the difference in inflation, shown in Figure 15.

Figure 15. Monthly, Volatility of Difference in Inflation

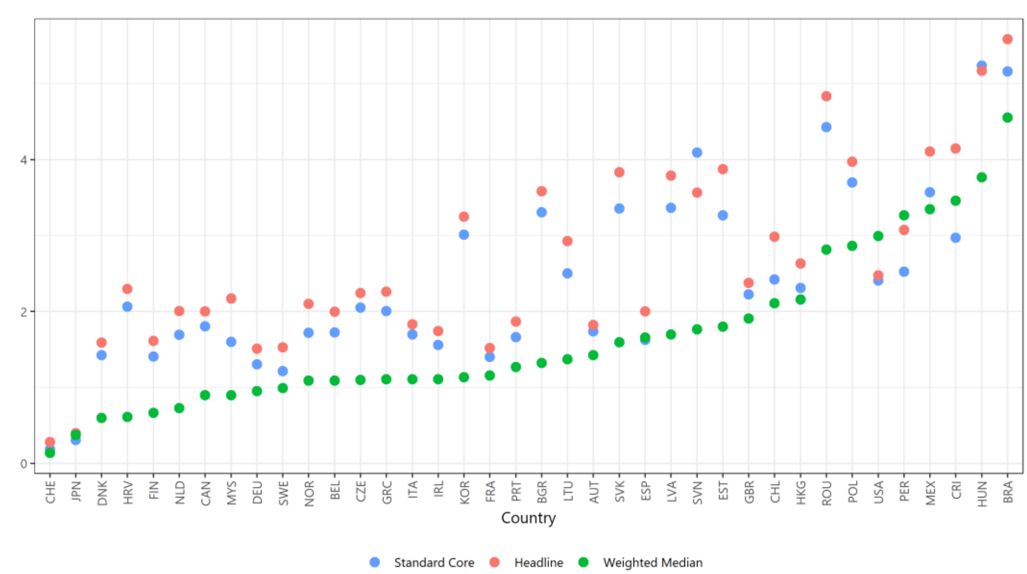


Source: Authors' calculations

A.2 Results on Mean

Turning to the results for the mean we find that at the monthly frequency the mean of weighted median (green) is below standard core (blue) and headline (red) inflation for all but a handful of countries (Figure 16).

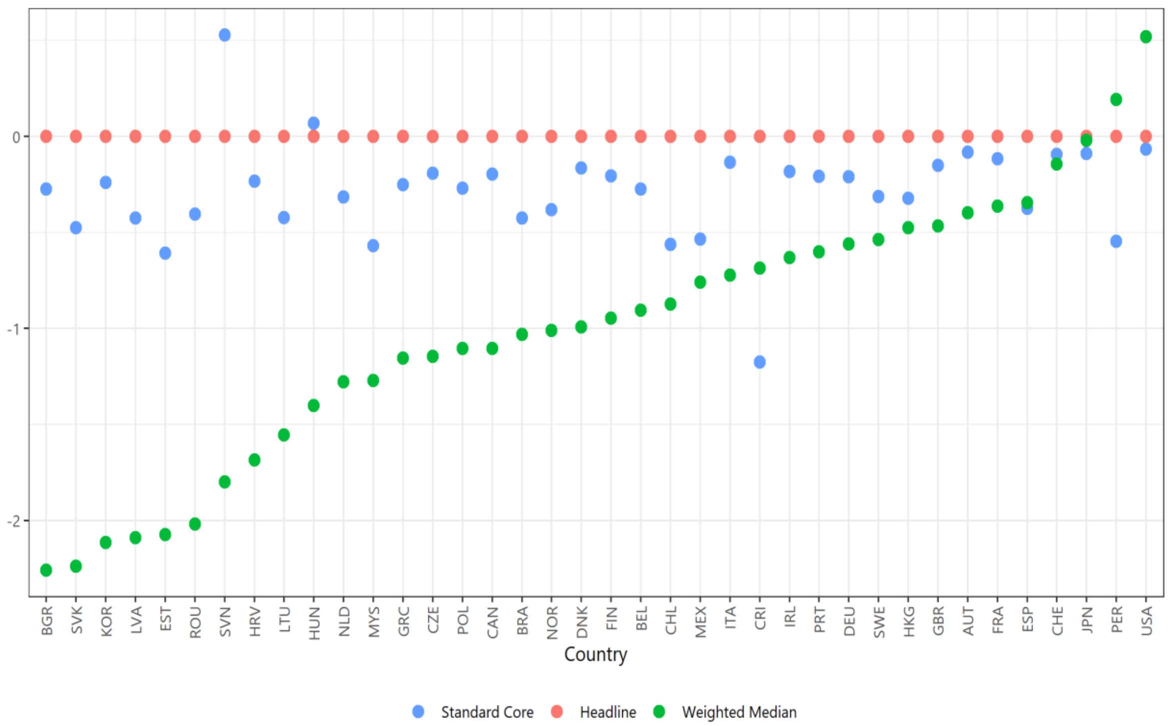
Figure 16. Monthly, Mean



Source: Authors' calculations

Graphing the mean to explicitly show the bias to headline highlights the negative bias of weighted median compared to headline inflation. The negative bias is severe for the monthly inflation metric (Figure 17) but is less prevalent at the quarterly frequency as shown in the main body of the paper (Figure 3). As with the quarterly inflation metric we find a positive bias for the USA.

Figure 17. Monthly, Bias to Headline

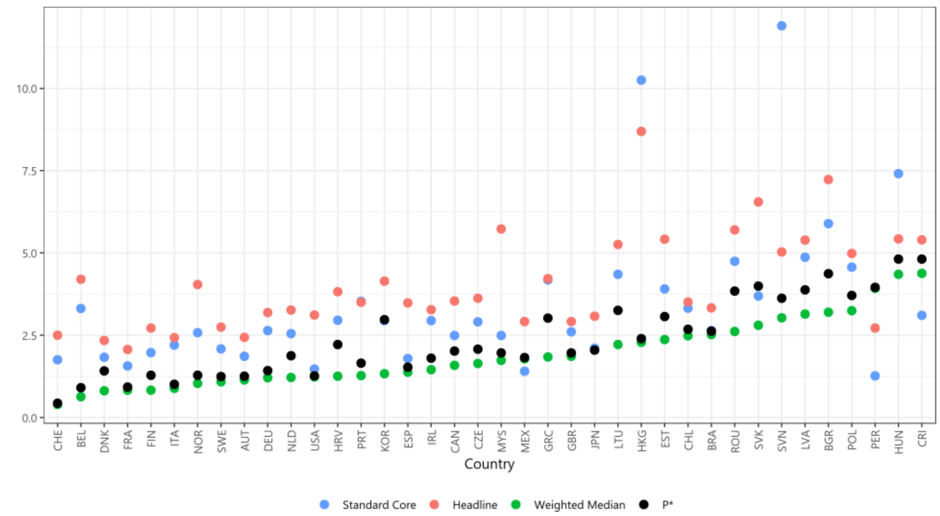


Source: Authors' calculations

A.4 Results on Volatility with P*

For the P* measure, which is the inflation measure that minimizes the bias, we show that volatility of inflation is close to the results for weighted median when using the monthly inflation metric (Figure 18). The volatility of the P* inflation measure (black) for the sample of our countries, is typically between the volatility of the weighted median (green) and standard (core). This shows the robust performance, as judged by the volatility, of the P* inflation measure while also minimizing the bias to headline inflation. This result is similar for the quarterly frequency as outlined in the main body of the paper.

Figure 18. Monthly with P*, Volatility

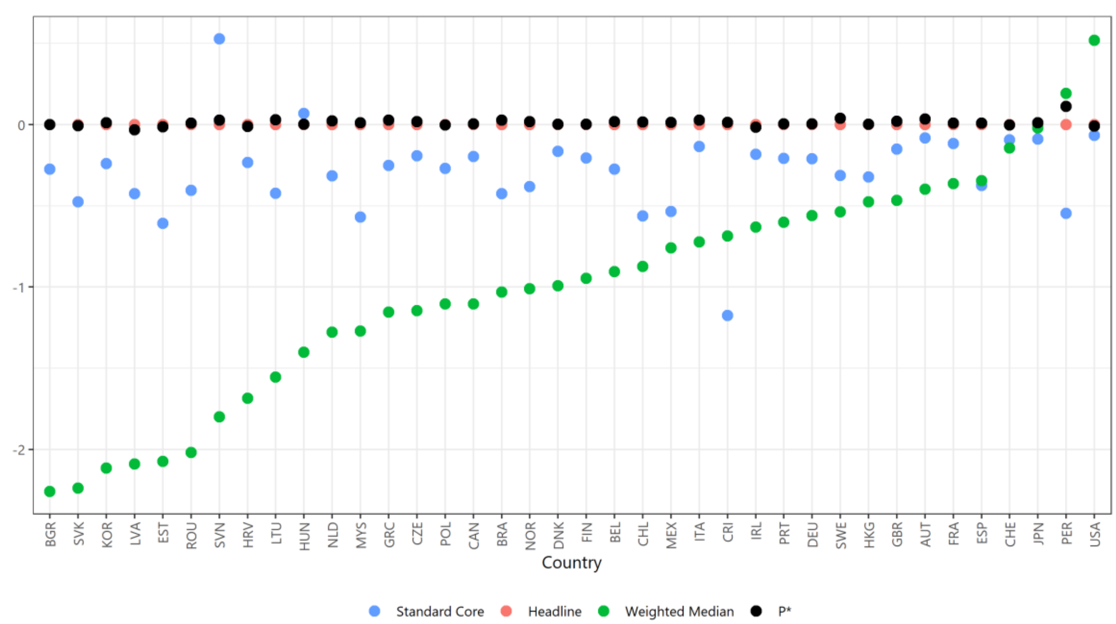


Source: Authors' calculations

A.5 Results on Bias to Headline with P*

By construction the mean of P* inflation measure (black) is close to headline inflation (red). Therefore, it is expected that the bias to headline for the P* inflation measure if minimized as shown in Figure 19.Hence, this measure greatly reduces the bias that can be seen between the weighted median (green) and headline inflation.

Figure 19. Monthly with P*, Bias to Headline

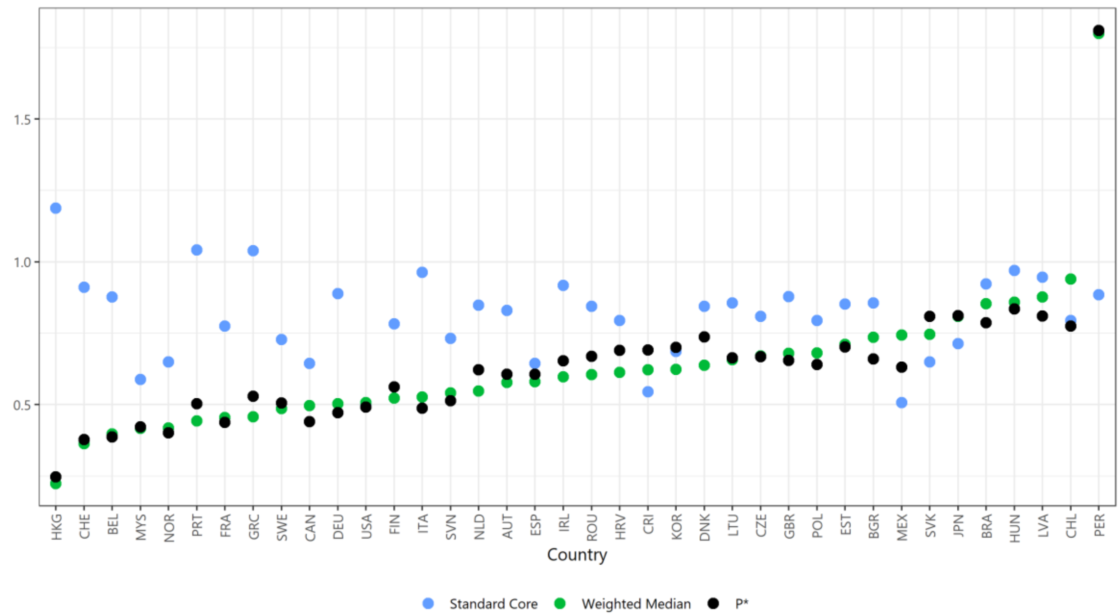


Source: Authors' calculations

A.6 Results on Capturing One-Year-Ahead Headline Inflation with P*

Overall, the performance of P* in capturing one-year-ahead headline inflation, measured by comparing the RMSE of the regression of the inflation measure to headline inflation one year ahead with the RMSE of a random walk of headline inflation, is between the weighted median (green) and standard core (blue). At the quarterly frequency (main body of the paper) and monthly frequency the P* measure generally performs comparably to the weighted median inflation measure.

Figure 20. Monthly, RMSE of Core Measures / RMSE of Headline Inflation

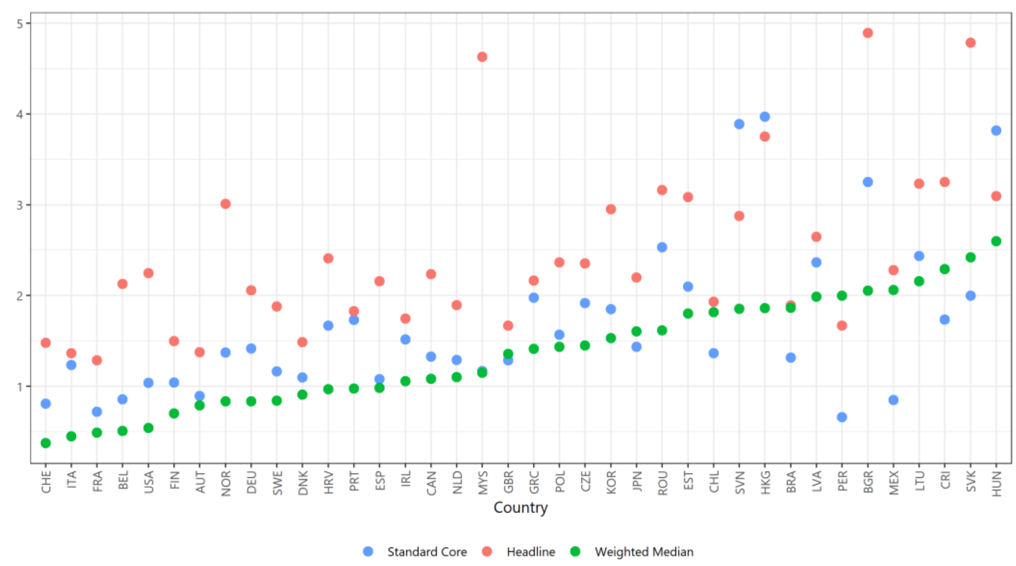


Source: Authors' calculations

B. Additional Quarterly Results

This section includes additional results that complement the findings in the main body of the paper. Figure 21 shows the volatility of the difference in inflation for quarterly inflation for the headline (red), standard core (blue) and weighted median (green). As we found for the volatility of inflation the weighted median inflation measure performs well (lower volatility) compared to standard core and headline inflation. The better performance of the weighted median is particularly true for advanced economies but is not always the case (GBR, JPN, SVK).

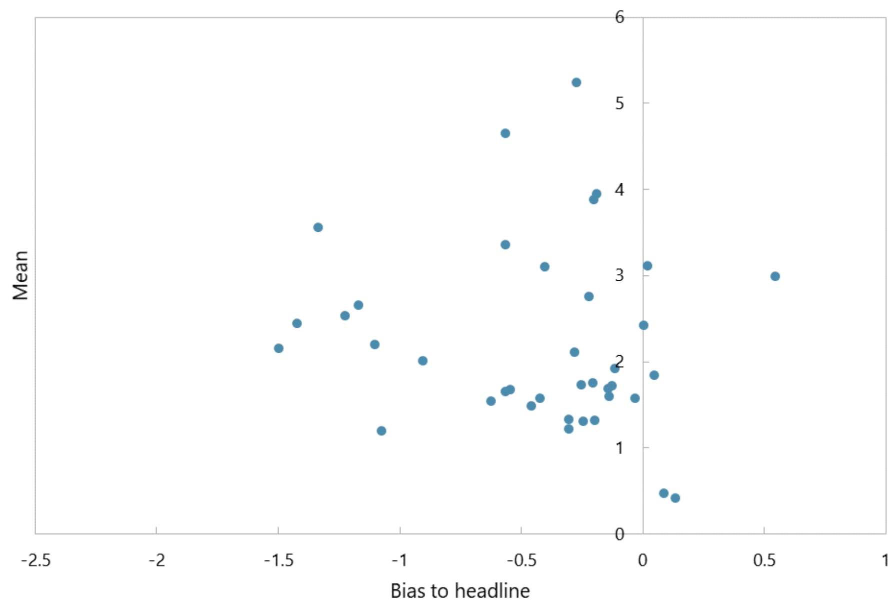
Figure 21. Quarterly, Volatility of Difference in Inflation



Source: Authors' calculations

In Figure 22 we show the weighted median bias to headline inflation on the *x-axis* and mean of weighted median on the *y-axis*. There does not seem to be a strong relationship between the bias to headline and mean, which means that even though the weighted median has, on average, lower mean for many countries in our sample compared to headline inflation, in these instances it is also the case that headline inflation is likely to present a low mean. Therefore, there is not a relationship between countries with low inflation during our sample period and the weighted median inflation measure having a larger bias.

Figure 22. Quarterly, Bias versus Mean

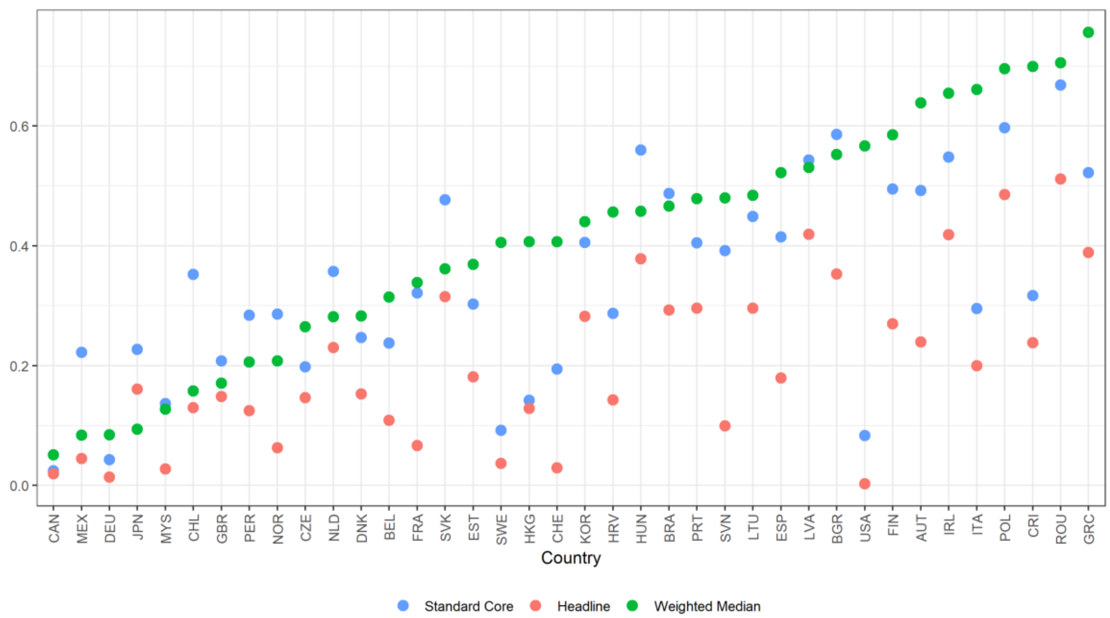


Source: Authors' calculations

To further complement the analysis conducted using a forward-looking Phillips curve we also test the performance of the inflation measures using a Hybrid Phillips curve. The Hybrid specification includes unconstrained backward and forward-looking inflation component as well as the output gap. A theoretical justification of such model is given in Galí and Gertler (1999), and follows that some agents may be resetting prices in a forward-looking manner whereas others follow a simple rule that includes historical prices.

We find that the goodness of fit (R^2) for the hybrid Phillips curve of the weighted median is better (higher) for the majority of countries than standard core. Moreover, both the Phillips curve that includes the standard core or weighted median inflation typically have a larger R^2 than when headline inflation is included. This is also found in the forward-looking Phillips curve in the main body of the paper shown in Figure 4.

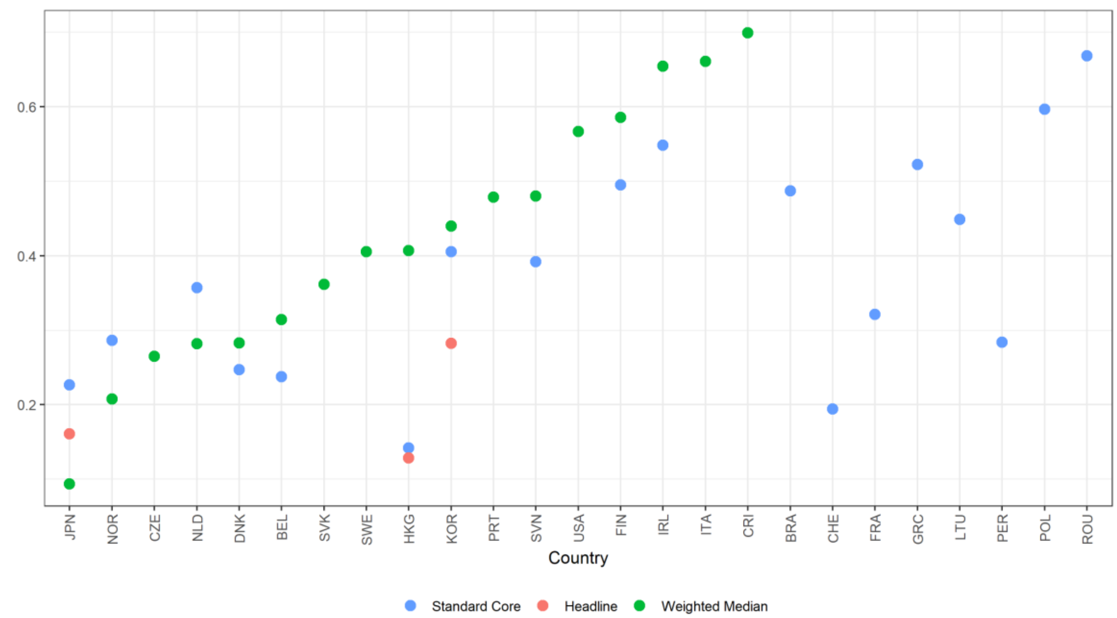
Figure 23. Phillips Curve, Hybrid Specification, R^2



Source: Authors' calculations

We find that our results are robust even when we restrict our analysis to only graph the results from the Hybrid Phillips curve that include positive and significant coefficient on the output gap (Figure 24). Overall the R^2 for the weighted median (green) is above the standard core (blue). Furthermore, we find more countries with hybrid Phillips curves where the coefficient on the output gap is positive and significant when inflation is measured by the weighted median compared to the standard core. Both the standard core and weighted median outperform headline inflation measure in the restricted results for all countries except Japan.

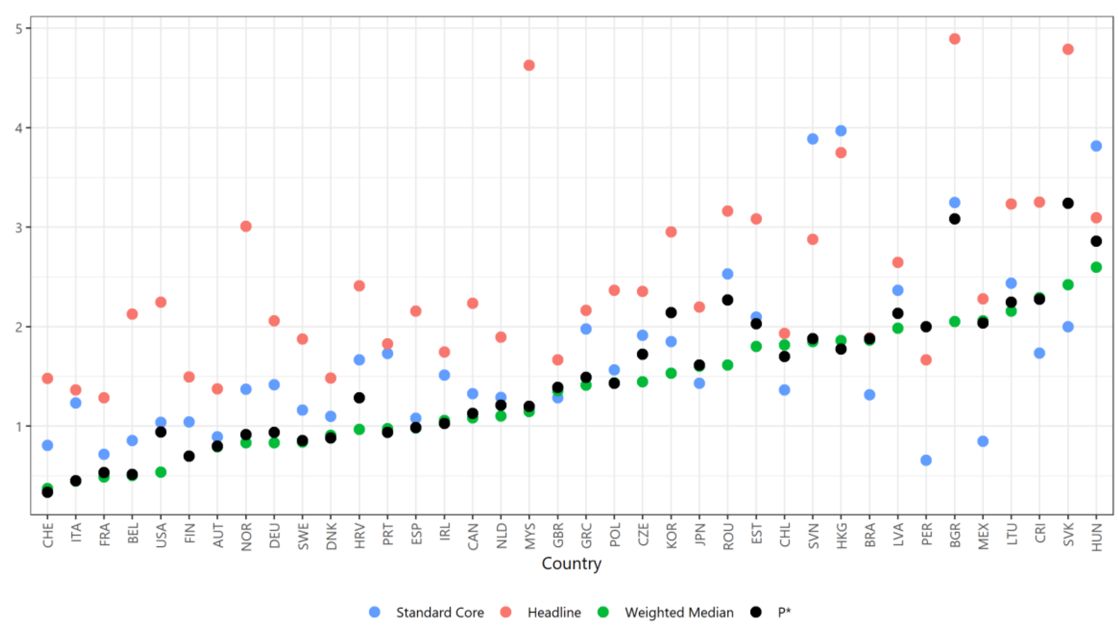
Figure 24. Phillips Curve, Hybrid Specification, R^2 Showing Only Results That Include Significant Coefficients



Source: Authors' calculations

In addition to previous analysis on the volatility of difference in inflation shown in this Appendix we also add to it the results for P*. As can be seen in Figure 25, the volatility of difference in inflation for P* is similar to that of weighted median and shows good performance overall for the countries in our sample, with some exceptions.

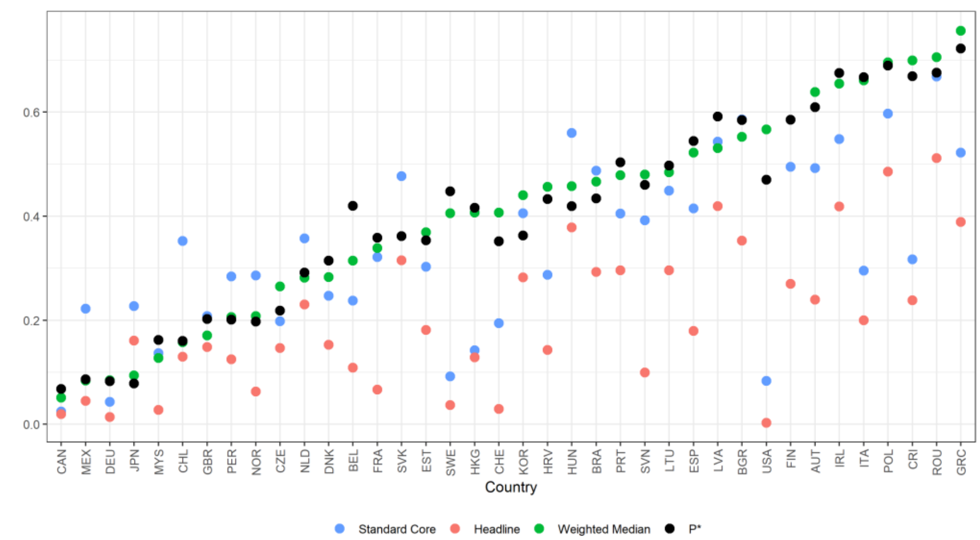
Figure 25. Quarterly with P*, Volatility of Difference Inflation



Source: Authors' calculations

P* also performs well in the hybrid Phillips curve as the R^2 is close to, and sometimes exceeding, the R^2 seen when we include the weighted median.

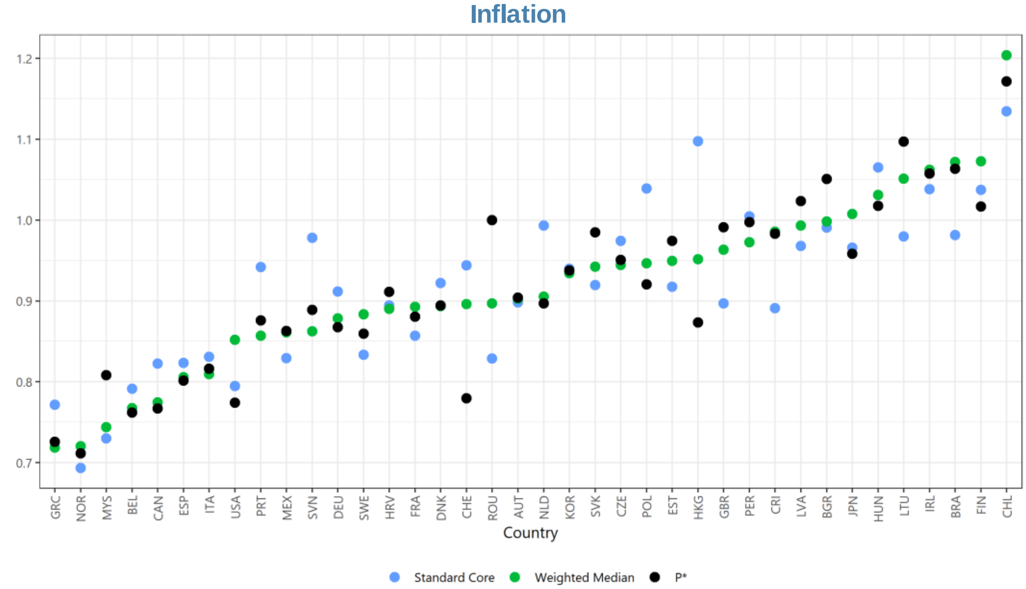
Figure 26. Phillips Curve, Hybrid Specification with P*, R^2



Source: Authors' calculations

In addition to the analysis of the monthly and quarterly inflation metric we analyze the relative RMSE to headline inflation using the 12-month inflation metric. For the 12-month inflation metric we find mixed results, where the performance of the weighted median and P* is not better for a majority of countries. In Figure 27 the relative RMSE of the standard core inflation on one-year ahead headline inflation compared to the RMSE of a random walk is below (better performance) than the equivalent calculation for the weighted median for about as many countries as the weighted median outperforms the standard core.

Figure 27. 12-Month, Random Walk, RMSE Core Measures / RMSE of Headline Inflation

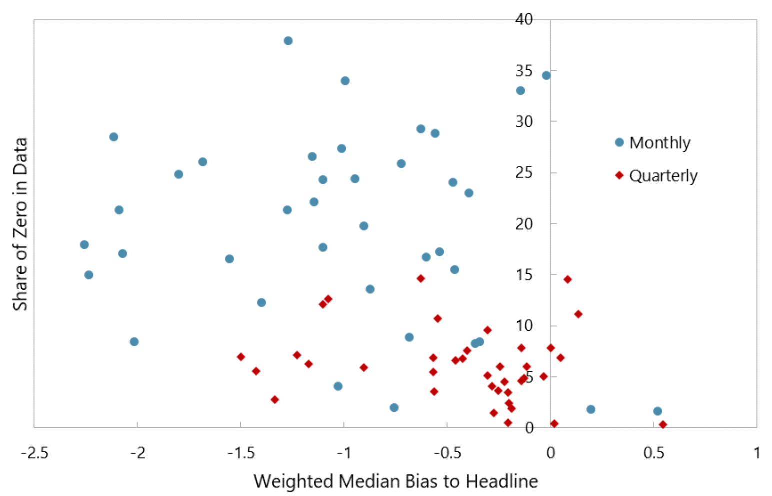


Source: Authors' calculations

C. Investigating the bias

The paper present evidence of an inflation bias for the standard core inflation and for the median inflation , i.e., their average inflation over the sample is quite different than that of the headline inflation. One possible reason is share of zeros in the sectoral inflation. To check this argument, we graph the bias for the monthly inflation metric and compare this to the share of zeros in the data. Figure 28 (below) compares the monthly to quarterly share of zeros in the data versus the bias to headline. The first observation is that the monthly frequency exhibits a higher share of zeros compared to the quarterly frequency. Indeed, it is reasonable to expect that the likelihood of a zero price change declines over time and hence is higher at the monthly than quarterly frequency. The second observation is that a higher shares of zeros at the monthly frequency is also associated with a larger bias, compared to quarterly.

Figure 28. Monthly and Quarterly, Bias Versus Share of Zeros



Source: Authors' calculations

D. Panel Phillips Curve Regression Tables

Below we outline the results of our baseline specification panel Phillips curve regression.

Table 2 presents the R^2 and Table 3 the output gap coefficients of our baseline Phillips curve regression presented earlier in the paper in Figure 5.

Table 2. Phillips Curve, Baseline Specification, R^2

Country	Headline	Standard Core	Weighted Median	P*
AUT	0.04	0.05	0.10	0.07
BEL	0.05	0.19	0.17	0.20
BGR	0.18	0.37	0.41	0.45
BRA	0.05	0.10	0.13	0.12
CAN	0.00	0.01	0.00	0.00
CHE	0.01	0.11	0.15	0.14
CHL	0.01	0.04	0.03	0.03
CRI	0.01	0.14	0.05	0.05
CZE	0.13	0.13	0.19	0.16
DEU	0.01	0.03	0.01	0.01
DNK	0.02	0.09	0.12	0.12
ESP	0.00	0.03	0.06	0.05
EST	0.09	0.24	0.31	0.28
FIN	0.17	0.30	0.33	0.33
FRA	0.03	0.10	0.09	0.08
GBR	0.02	0.01	0.03	0.02
GRC	0.09	0.18	0.17	0.15
HKG	0.04	0.07	0.16	0.17
HRV	0.06	0.20	0.26	0.32
HUN	0.00	0.00	0.00	0.01
IRL	0.06	0.06	0.07	0.07
ITA	0.05	0.04	0.14	0.14
JPN	0.08	0.07	0.03	0.02
KOR	0.17	0.29	0.31	0.27
LTU	0.16	0.38	0.39	0.39
LVA	0.32	0.49	0.48	0.52
MEX	0.01	0.01	0.00	0.00
MYS	0.01	0.07	0.02	0.07
NLD	0.08	0.13	0.12	0.14
NOR	0.02	0.20	0.17	0.17
PER	0.00	0.07	0.04	0.04
POL	0.15	0.23	0.26	0.24
PRT	0.03	0.05	0.09	0.08
ROU	0.01	0.02	0.01	0.01
SVK	0.01	0.02	0.06	0.05
SVN	0.06	0.30	0.33	0.35
SWE	0.01	0.01	0.08	0.11
USA	0.00	0.06	0.33	0.15

Source: Authors' calculations

Table 3. Phillips Curve, Baseline Specification, Coefficient on the Output Gap

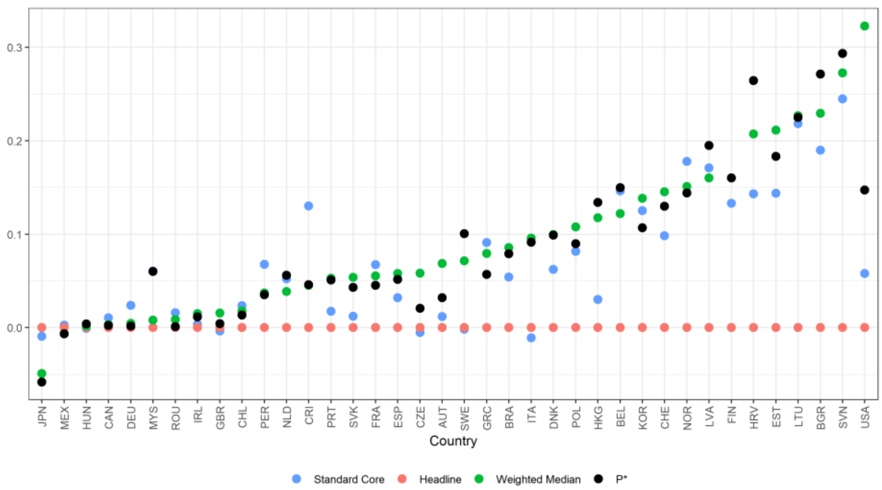
Country	Headline	Standard Core	Weighted Median	P*
AUT	-0.10	0.04	0.08	0.07
BEL	0.33	0.25***	0.19**	0.21**
BGR	0.92*	1.13***	0.86***	1.26***
BRA	0.3*	0.32**	0.4**	0.43**
CAN	-0.01	0.08	0.04	0.03
CHE	0.11	0.25**	0.14*	0.12
CHL	0.10	0.14	0.15	0.14
CRI	-0.05	0.13	0.10	0.10
CZE	0.43**	0.37**	0.34***	0.35***
DEU	0.08	0.12	0.05	0.05
DNK	0.16	0.22**	0.22**	0.22**
ESP	-0.01	0.09	0.11	0.10
EST	0.28	0.32*	0.28**	0.31**
FIN	0.36***	0.38***	0.35***	0.35***
FRA	0.16*	0.17***	0.13*	0.13*
GBR	0.10	0.05	0.1*	0.08*
GRC	0.26**	0.32***	0.23**	0.24**
HKG	0.26*	0.35**	0.36***	0.37***
HRV	0.23	0.33*	0.28	0.42*
HUN	0.10	0.10	0.12	0.15
IRL	0.18	0.17*	0.14*	0.14
ITA	0.18	0.12	0.18	0.18
JPN	0.35***	0.25***	0.18**	0.15*
KOR	0.61***	0.57***	0.53***	0.59***
LTU	0.39	0.48***	0.45***	0.51***
LVA	0.56*	0.63**	0.54**	0.62**
MEX	-0.08	-0.05	0.03	0.03
MYS	0.23	0.2*	0.10	0.19
NLD	0.33*	0.35**	0.3*	0.36*
NOR	0.38	0.64***	0.37***	0.39***
PER	-0.02	0.05**	-0.12	-0.11
POL	0.78**	0.89**	0.68**	0.73**
PRT	0.19	0.20	0.19	0.18
ROU	0.12	0.19	0.10	0.11
SVK	0.21	0.17	0.27**	0.33**
SVN	0.23	0.36***	0.24***	0.29***
SWE	0.11	0.07	0.16*	0.19*
USA	0.12	0.2**	0.36***	0.31***

*** p-value <0.01, ** p<0.05, *p<0.1

Source: Authors' calculations

Figure 29 displays the difference in R^2 in the baseline Phillips curve specification with our inflation measures compared to the R^2 when using headline inflation. As is evident also in Figure 4, the Phillips curve with our baseline specification using weighted median inflation or P*, on the whole, substantially outperforms for the majority of countries the equivalent Phillips curve that uses standard core or headline inflation.

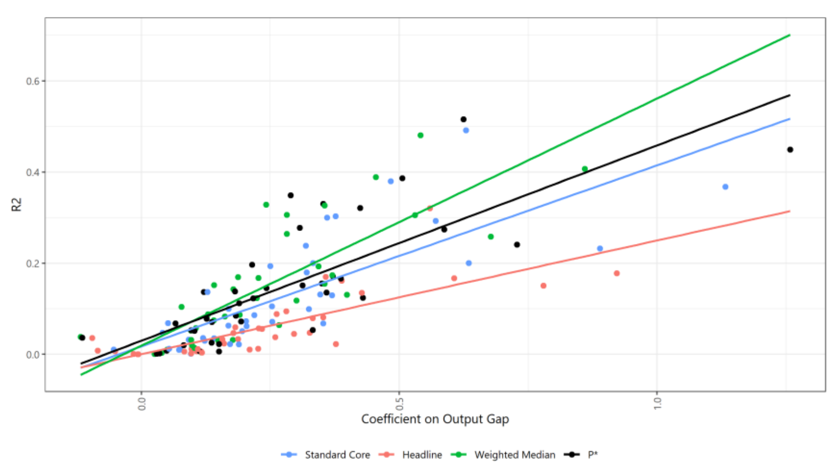
Figure 29. Phillips Curve, Baseline Specification, Difference in R^2 with Headline



Source: Authors' calculations

Figure 30 shows the relationship between the R^2 and coefficient on the output gap for the baseline Phillips curve specification by inflation measure (represented by different colors) and countries (dots in the scatter plot). The Figure shows that, as generally expected, a larger coefficient on the output gap is accompanied by a higher R^2 in the baseline Phillips curve regression. However, the relation tends to be strongest for the median inflation, and weakest for headline inflation, with P* and core inflation offering intermediate outcomes.

Figure 30. Phillips Curve, Baseline Specification, R^2 and Coefficient on the Output Gap



Source: Authors' calculations