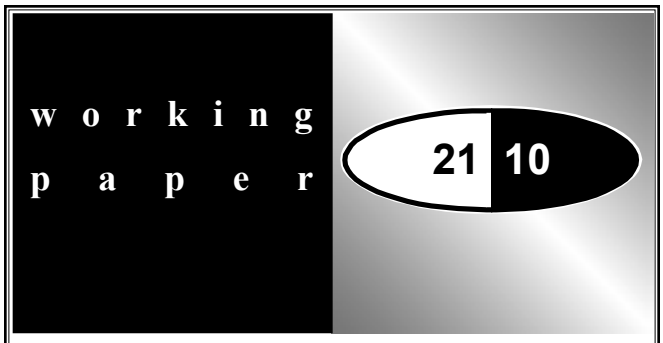

Is It Time to Reassess the Focal Role of Core PCE Inflation?

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In this paper, I review the history of "core" PCE inflation and its rationale: remove volatile items with transitory shocks to better highlight the trend in inflation. Structural changes in the inflation process imply that, on a "reducing volatility" basis, the list of items excluded from the "core" inflation basket (aside from gasoline) is far from optimal. This is true whether one assesses volatility on the basis of a weighted component monthly, or an index monthly, or a 12-month index, or a 5-year index. In addition, I demonstrate other deficiencies of exclusion indexes. Excluded items do not just experience transitory shocks, but also have persistent trends; thus excluding them imparts a significant time-varying bias to core inflation. Meanwhile, items that are not excluded can experience volatility and moreover can cause core inflation to depart notably from trend inflation, sometimes at crucial moments. Two other prominent trend inflation measures, trimmed mean PCE inflation and median PCE inflation, gracefully address these issues, but themselves have notable time-varying bias. I discuss the source of the bias in these other measures and how to correct for bias in real time. I then summarize and extend a wide variety of evidence comparing these three trend measures. I conclude that, for a variety of considerations that are relevant for monetary policy deliberations and communication, either trimmed mean PCE inflation or median PCE inflation are superior measures.

Keywords: core inflation, forecasting, monetary policy, trimmed mean, median.

JEL codes: E0, E31, E37, E52, C8.

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Introduction

In January 2012, the Federal Open Market Committee (FOMC) announced an explicit inflation target of 2 percent, as measured by the annual change in the personal consumption expenditures price index (PCEPI). However, the FOMC also pays attention to other inflation measures. Of these, "core" PCE inflation – the annual change in the PCEPI-less-food-and-energy – plays a focal role in monetary policy deliberations and communication. Forecasts of core PCE inflation rates are provided in publicly available historical Tealbooks and are reported in the quarterly Summary of Economic Projections (SEP) of FOMC members. Both sources may be taken to indicate core inflation's focal role in monetary policy discussions. FOMC communications often reference core PCE inflation; for instance, the February 2020 Monetary Policy Report says: "The 12-month change in the price index for personal consumption expenditures (PCE) was 1.6 percent in December 2019, as was the 12-month measure of inflation that excludes food and energy items (so-called core inflation), which historically has been a better indicator of where inflation will be in the future than the overall index (figure 8)." The January 2020 FOMC statement refers to "inflation for items other than food and energy," as the statement often does.

The Federal Reserve announced in November 2018 that it would conduct a broad review of the strategy, tools, and communication practices it uses to pursue the monetary policy goals established by Congress.[1] For instance, the FOMC is planning to make some enhancements to its quarterly SEP as part of this framework review (Ryser and Yung, 2020). Thus, it is an appropriate time to ask the question: Is it time to reassess the focal role of core PCE inflation in monetary policy deliberations and communication?

Yes. I demonstrate that, because of changes in the inflation process, the current exclusion list of core PCE is outdated. The extant list gives rise to three phenomena. First, core inflation has excess volatility, relative to an exclusion basket selected to reduce volatility in the index. Second, as a result of persistent relative price movements, excluded items impart a significant time-varying bias to the index. Third, because other items in the basket can experience very large shocks, core PCE inflation sometimes veers significantly from trend inflation. Two other trend inflation measures, trimmed mean PCE inflation (hereafter, trimmed PCE) and median PCE inflation (hereafter, median PCE), do not suffer from "fixed basket" deficiencies, more adequately remove volatility, and more accurately track trend inflation. But these alternatives are themselves subject to a notable time-varying bias. Despite this, an abundance of evidence, both theoretical and empirical, indicates that either of these alternatives would serve better in a focal role than core PCE inflation (hereafter, core PCE), both in policy deliberations and in policy communication.[2]

A Brief History of Core Inflation

Core inflation was invented as a simple and practical method to allow people to discern the underlying trend in inflation. Monthly movements in the "headline" personal consumption expenditures price index (hereafter, headline PCE) and in the "headline" consumer price index (hereafter, headline CPI) are

[1] https://www.federalreserve.gov/monetarypolicy/review-of-monetary-policy-strategy-tools-and-communications.htm
[2] Another recent paper on this topic is Dolmas and Koenig (2019). For a somewhat different viewpoint, see Luciani and Trezzi (2019).

computed using a weighted average[3] of the average cost or price changes of numerous components (such as gasoline, college tuition, fresh produce, and men's shoes). Both headline inflation measures are volatile; they often move sharply on a monthly basis, or even on a 12-month basis, because some components experience very large shocks. Since these large shocks often revert, they obscure the underlying trend in inflation. To identify that trend, one would like to strip out large, transitory shocks. In the 1970s, it was thought that "core" inflation accomplished this goal.

During the 1970s, when the economy faced large oil price shocks and volatile movements in food prices, headline inflation experienced a lot of volatility, making it difficult for policymakers to discern the trend in inflation. In response to this challenge, the CPI-less-food-and-energy index, popularly called "core" CPI, was developed.[4] The core CPI is constructed in the same way as headline CPI, except it simply excludes most food and energy items, and its movements are determined by the weighted average inflation rate of the remaining items. Removal of these components, components that were both important and "thought to be subject to large, temporary price changes" (Clark, 2001), was intended to provide a means of reducing "noise" in CPI inflation, thereby helping policymakers and analysts to better discern the underlying trend in CPI inflation.[5] Though there are some small differences in its excluded components, the motivation for the core PCE price index is the same: It is believed that excluding food and energy items is a simple and effective means of providing information on the underlying trend in PCE inflation.[6] In this article, I re-evaluate core PCE from several perspectives.

From a volatility perspective, the core PCE basket is outdated

From the perspective of reducing volatility, the basket is outdated: The list of excluded components does not match the list that reduces volatility the most.

The inflation process has changed since the 1970s. Monetary policy has changed markedly (see, e.g., Ashley, Tsang, and Verbrugge (2020)) and the global economy is much more integrated. There have been major changes in available goods and services and in preferences. As a result, aggregation weights and volatilities have changed since the 1970s. Clark (2001) noted the volatility changes almost two decades ago, and many others have noted it since then. But weights matter too, because a component with negligible weight cannot influence headline inflation appreciably. In fact, both the weighted

[3] A given component's aggregation weight corresponds to its importance in the consumption basket of a typical consumer.
[4] Core inflation indexes were more or less invented in the 1970s. As Wynne (2008) notes, the *CPI Detailed Report* for January 1978 was the first to routinely include the CPI All Items less Food and Energy measure. Prior to this, from December 1975 this measure was reported every three months in a special table. However, other exclusion indexes, particularly all items excluding food, and all items excluding shelter, had been occasionally published by the Bureau of Labor Statistics in *Monthly Labor Review* articles. The earliest Fed publication on core or underlying inflation is Scadding (1979). Dolmas and Koenig (2019) note that the BLS began reporting exclusion-based measures periodically as early as 1957. See the 1957 CPI reports archived at the Federal Reserve Bank of St. Louis's FRASER: https://fraser.stlouisfed.org/title/58. Dolmas and Wynne provide more details about the history of core inflation and the development of alternative measures of trend inflation.
[5] "Importance" in the index matters because a component with little weight will have little impact on the index, even if it is volatile (see discussion below). Regarding the rationale for core inflation, it is also possible that policymakers held the viewpoint that they did not have much control over the prices of internationally traded oil or food prices that are subject to weather shocks. Since formal theory does not imply that core PCE inflation adequately filters out "international" or "supply" shocks – to properly identify such shocks, one must have a structural model – I do not further consider such justifications in this paper.
[6] For more details about how the PCE index and CPI index differ, see Binder, Janson, and Verbrugge (2020).

variance and weighted covariance matter; removing a component with high weighted covariance will reduce the volatility of the index. And weights have changed a lot (see the Appendix): New autos have become far less important, and personal computers did not even exist in the 1970s. Since both changes in the volatility of various components and changes in aggregation weights will change the volatility of core inflation and its ability to identify trend inflation, a review of the basket is necessary.

I begin with the simplest approach to assessing basket volatility. In Table 1, I rank items by their weighted volatility (column 2).[7] This ranking ignores the contributions of covariance, but gives a sense in which various items contribute to the volatility of headline PCE inflation. Items highlighted in green are excluded from core PCE. Notice that only three items that are excluded from core PCE make this top-15 list. Gasoline is very volatile and has a relatively large weight, so its weighted volatility is the largest, by far.[8] But the next 11 most volatile items are all *included* in core PCE![9] The sum of their weighted volatility is nearly equal to that of the energy components. Hence, from a "reducing volatility" perspective – the reason core inflation was invented – the core PCE basket appears to leave much to be desired.

Weighted volatility, 1985-2019	Weighted volatility, 2005-2019	PCE Component
1.23	1.51	Gasoline and other motor fuel
0.42	0.30	Financial service charges, fees, and commissions
0.27	0.21	Final consumption expenditures of nonprofit institutions serving households
0.23	0.19	Air transportation
0.19	0.13	Nonprofit hospitals' services to households
0.19	0.13	Owner-occupied stationary homes
0.17	0.19	Commercial banks
0.16	0.16	Physicians' services
0.14	0.17	Prescription drugs
0.13	0.14	Women's and girls' clothing
0.12	0.13	Hotels and motels
0.12	0.09	Computer software and accessories
0.11	0.12	Natural gas
0.11	0.11	Electricity
0.09	0.10	Other depository institutions and regulated investment companies

Table 1. Top-15 components in the PCE price index, ranked by weighted volatility. Source: BEA, author's calculations. Items highlighted in green are excluded from core PCE.

[7] The "volatility" of an index is measured as its standard deviation. I compute $w_i\sigma_i$ where w_i is component i's aggregation weight in 2019, and σ_i is the monthly standard deviation of the annualized growth rate of that component, either over the 1985-2019 period or over the 2005-2019 period. The most volatile item over the 1985-2019 period was life insurance owing to two outliers associated with the September 11th attacks.

[8] This finding is implicit in the nowcasting models of Knotek and Zaman (2017).

[9] The item ranked 6th, owner-occupied stationary homes, has a notable weighted volatility because of its very high weight; it is not very volatile.

On a volatility basis, other authors have noted that the basket should be updated, often pointing to the decline in food volatility and the high volatility in components outside of food and energy; see Clark (2001), Gavin and Mandal (2002), Detmeister (2012), or Stock and Watson (2016).

Having said that, as noted above, the volatility of core inflation is also influenced by weighted covariances.[10] One can simultaneously account for all the contributions of a given commodity to volatility by simply excluding it and computing the volatility of the resulting index. Because the covariance contribution of any item depends upon the other items that remain, I remove components one by one, in order of their contribution to overall volatility.[11] But monthly volatility is only one way to measure volatility. Indexes are often examined as 12-month changes, so the contribution to 12-month volatility might be more important. Furthermore, it is also interesting to consider each item's contribution to 5-year volatility. In Table 2, I report the resulting lists of components and their additional contribution to removing volatility, at the monthly, 12-month, and 5-year horizons. As in Table 1, commodities highlighted in green are excluded from core inflation.

	monthly		12-month		5-year	
volatility of headline		2.317		1.088		0.714
	component	reduction	component	reduction	component	reduction
	Gas	0.894	Gas	0.240	NonPr hosp	0.071
	Life ins	0.118	NonPr hosp	0.064	Phys srvcs	0.045
	Fin srvcs	0.040	Phys srvcs	0.036	Gas	0.043
	Air trans	0.034	Computers	0.017	Gov hosp	0.022
	Nat gas	0.026	Gov hosp	0.016	Computers	0.018
	W clothes	0.019	Life ins	0.016	Health ins	0.016
	NonPr hosp	0.020	Fuel Oil	0.014	Games	0.014
	Jewelry	0.020	Games	0.013	Prop hosp	0.014
	Fresh Veg	0.019	Health ins	0.011	Life ins	0.013
	Tobacco	0.019	Prop hosp	0.010	Para med	0.012
	Phys srvcs	0.018	Telephone	0.009	Telephone	0.011
	Fuel oil	0.015	TVs	0.008	TVs	0.010
	House linen	0.011	Jewelry	0.008	Software	0.009
	Software	0.010	Air trans	0.008	Jewelry	0.008
	Electricity	0.010	Software	0.008	Tobacco	0.008

Table 2. Reduction in volatility from sequential removal of various components, by measure of volatility, ranked. Source: BEA, author's calculations. Items in green are excluded from core PCE. Abbreviations: Air trans: air transportation; Computers: personal computers/tablets and peripheral equipment; Fin srvcs: financial service charges, fees, and commissions; Fresh Veg: vegetables (fresh); Games: games, toys, and hobbies; Gas: gasoline and other motor fuel; Gov hosp: government hospitals; Health ins: Net health insurance; House linen: household linens; Life ins: life insurance; Nat gas: natural gas; NonPr hosp: nonprofit hospitals' services to households; Para med: paramedical services;

[10] Furthermore, when an item is removed, all remaining weights need to be increased, so that the weights still sum to one.
[11] It is interesting to note that removing some items will increase rather than reduce volatility. For instance, removing owner-occupied stationary homes increases the standard deviation of 12-month headline inflation from 1.09 to 1.20.

Phys srvcs: physician services; Prop hosp: proprietary hospitals; Software: computer software and accessories; Telephone: telephone and related communication equipment; TVs: televisions; W clothes: Women's and girls' clothing.

There are a number of interesting conclusions. First, the ranking in column 1 of Table 2 does not perfectly coincide with that in Table 1, indicating the important role of weighted covariance. Second, as in Table 1 – with the exception of gasoline – the list of items excluded from core inflation bears little resemblance to the rankings here. Even if one were concerned only with monthly volatility, only 4 of the top 15 items are excluded from core. Third, healthcare-related items, including nonprofit hospitals' services and physicians' services, are quite important for volatility over longer periods. The contribution of life insurance to volatility is notable at all horizons. Fourth, for five-year volatility, gasoline ranks third. This implies that it experiences large shocks that are very persistent – not the sorts of shocks that core inflation was intended to remove. I discuss this below. In short, by any of these metrics, the core basket is outdated.[12]

Core inflation is sensitive to outliers

An outlying observation, or outlier, is an observation that is markedly far from the middle of the distribution. In the inflation context, when the monthly inflation rate experienced by a given component is very different from 2 percent, that observation is an outlier. In the inflation context, outliers are common. In any given month, it is not at all unusual to see component inflation rates as small as -20 percent or as large as +20 percent.

When a component is dropped, the aggregation weight on all remaining components rises. This means that core inflation is even *more* sensitive than headline inflation to outlier observations in the *remaining* components. This sensitivity is reflected in the volatility that remains in core inflation. More importantly, this sensitivity can cause core inflation to veer away from trend inflation and can create communication challenges. For instance, in early 2019, core inflation dropped sharply in response to an outlier in telecom price movements, necessitating discussion in official communications. Even more problematically, the inclusion of outliers implies that core PCE can move in misleading ways.

An important example arose as the Great Recession began to unfold. Figure 1 depicts the movements of four simple trend inflation indexes from 2008-2010. Market-based core PCE is similar to core PCE, except that it includes only those components whose movements are driven by market prices. (In other words, all components whose transactions do not occur with observable market prices – and thus, whose "price" movement must be estimated by the Bureau of Economic Analysis (BEA) – are excluded.[13]) Thus, significant divergences between core PCE inflation and market-based core PCE inflation are driven by nonmarket price movements that are outliers. Similar to market-based core PCE, core CPI also excludes almost all components whose transactions do not occur with observable market prices. Trimmed mean PCE inflation, studied below, will always exclude outlier observations. Hence, if core inflation then diverges from the other three trend inflation indicators, this must be driven by sharp nonmarket price movements.

[12] This conclusion also holds if one is interested in selecting a basket that makes core inflation adhere most closely to ex-post measures of trend inflation; see below.

[13] Some important nonmarket goods included in core PCE are margins on used vehicles; financial services furnished without payment; and most insurance purchases.

With this in mind, notice the unusual behavior of 12-month core PCE inflation in late 2008, when it fell much faster than market-based core PCE. Further, notice its *highly misleading* behavior in late 2009/early 2010, when core PCE inflation experienced a strong rebound, suggesting that trend inflation was picking up speed. This signal was misleading. Other trend indicators, *including core CPI inflation*, fell more slowly, experienced little or no rebound, and continued to decline until late 2010. (A similar dynamic, though less pronounced, occurred after the 2001 recession, from early 2002 to early 2003.) Over the period in question, the anomalous movements were almost entirely driven by movements in the imputed price of financial services, driven by movements in the stock market.[14]

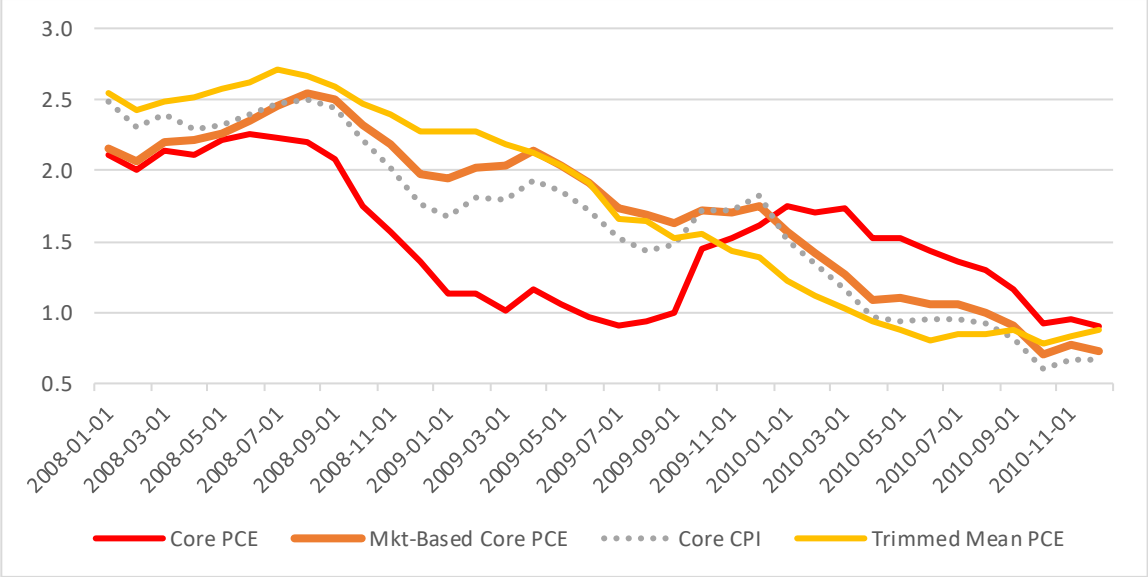

Figure 1. Anomalous Movement of Core PCE Inflation over the Great Recession and Early in the Recovery. Source: BEA, BLS, Federal Reserve Board via FRED.

Because volatile items remain in the core PCE basket, core PCE movements are quite volatile compared to two other simple trend inflation measures, trimmed mean PCE inflation and median PCE inflation.[15,16] This sensitivity makes it more volatile than the two alternative measures of trend inflation

[14] In making this assessment, I sum the weighted movements of these four components: commercial banks, other depository institutions and investment companies, pension funds, and financial service charges, fees, and commissions. Between January and June 2009, movements in these four components reduced core PCE inflation by over 0.6 percentage points per month, accounting for most of the gap between core PCE and market-based core PCE. In 2010, these components increased core PCE inflation by about 0.4 percentage points per month, entirely accounting for the gap between core and market-based core PCE. Regarding nonmarket insurance prices, household insurance premiums and normal losses are treated as market goods, since there are deflators for these available in the CPI. However, medical and hospitalization insurance, income-loss insurance, life insurance, motor vehicle insurance, and workers' compensation insurance are treated as nonmarket goods.

[15] I restrict attention to simple trend inflation measures because more complex trend measures are usually judged unsuitable for monetary policy communication. For more discussion, see Carroll and Verbrugge (2019) or Higgins and Verbrugge (2015a, 2015b).

[16] As another example, in the April 2021 CPI release, one component, car and truck rental, experienced its largest monthly increase in history: over 500 percent at annualized rates! Used cars and trucks came in at "merely" 215 percent. These components will enter with their full weight into the core PCE in April, but will not influence trimmed mean PCE and median PCE in April.

considered here. Since 1985, the standard deviation of the four-quarter change in quarterly core PCE growth is 0.97 percentage points, versus 0.65 percentage points for trimmed mean PCE and for median PCE.

Relative Price Movements and Bias in Trend Inflation Measures

A third deficiency in the core PCE basket stems from persistent relative price movements of excluded items. Perhaps the most important of these relates to energy. Figure 2 below depicts the 10-year moving average of the relative price of energy (that is, the price of energy goods and services divided by core PCE) from 1990 onward, with this ratio normalized to 1 in January 1990. As noted above, energy prices have a lot of transitory volatility; that is, energy inflation bounces around a lot from month to month. Getting rid of such transitory volatility is a central reason for omitting these prices from core PCE. But energy prices have *sustained* movements as well. For instance – as shown in Figure 2 – between 1998 and 2009, the relative price of energy rose by about 50 percent. Such sustained movements in energy prices are part of the inflation trend and should *not* be omitted from core PCE. Their omission will cause core inflation to depart from headline inflation for extended periods, so that core inflation gives a misleading signal of trend inflation. Putting this more formally, sustained movements in energy price inflation give rise to significant time-varying bias in core PCE inflation.[17]

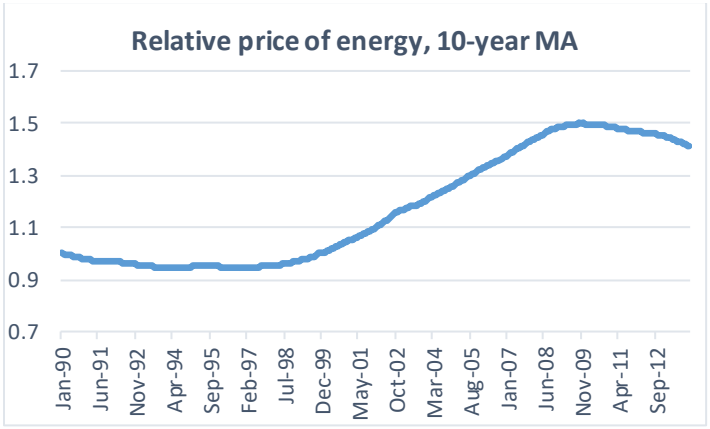

Figure 2. Ten-year moving average of the relative price of energy. Source: BEA via HAVER, author's calculations.

To study the 10-year bias in core PCE and to compare it to the bias in two other simple trend inflation measures, trimmed mean PCE and median PCE, I analyze rolling 40-quarter-mean core, trimmed mean, median, and headline PCE inflation. In particular, I focus on three differentials or "gaps": the 10-year average of quarterly core PCE inflation minus the 10-year average of quarterly PCE inflation; the 10-year average of quarterly trimmed mean PCE inflation minus the 10-year average of quarterly PCE inflation; and the 10-year average of quarterly median PCE inflation (minus 0.5 percentage points, a fixed bias adjustment) minus the 10-year average of quarterly PCE inflation. I plot these in Figure 3. It is

[17] Sustained relative price movements of food will also induce time-varying bias, as indeed will sustained relative price movements of *included* items (since these items receive higher weight than they do in headline PCE). For brevity, I illustrate the point using energy.

evident that the 10-year bias of core PCE inflation often exceeds that of the other two trend inflation measures.[18]

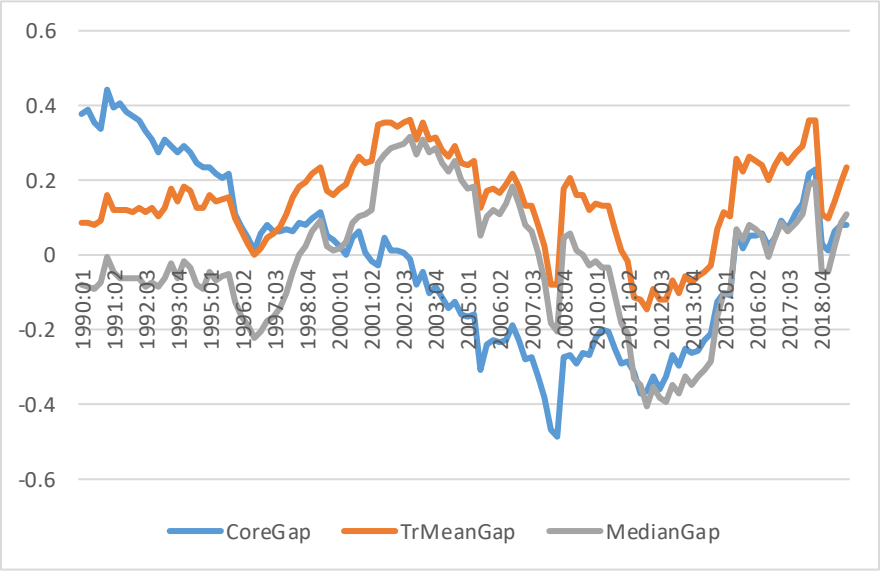

Figure 3. Time-Varying Differential of Trend Inflation Measures Against Headline PCE Inflation, 10-Year Moving Averages of Quarterly Data. Source: BEA retrieved via Haver Analytics, Federal Reserve Board, Federal Reserve Bank of Cleveland, author's calculations.

How closely do each of these measures adhere to headline inflation over 10-year horizons? Over the 1995-2019 period,[19] on a 10-year moving-average basis, median PCE inflation (after applying the 0.5 percentage points fixed bias adjustment[20]) was slightly closer to headline inflation on average – its RMSE was 0.19, versus 0.20 for both of the other measures. Trimmed mean inflation had a far smaller *range* of bias (column 4) and is arguably thus favored by this criterion.

	RMSE of 10-year MA, 1995-2019	**Maximum positive differential**	**Maximum negative differential**	**Range (Max + Min)**
Core PCE	0.20 ppts	0.23 ppts	0.49 ppts	0.72 ppts
Trimmed Mean PCE	0.20 ppts	0.36 ppts	0.15 ppts	0.51 ppts
Median PCE	0.19 ppts	0.32 ppts	0.41 ppts	0.72 ppts

Table 3. Source: BEA via Fred, Federal Reserve Bank of Cleveland, Federal Reserve Board, author's calculations.

[18] The fact that core inflation bias averages out over *very long* periods of time is not very relevant.
[19] While Table 3 values refer to the 1985-2019 period (thus starting in 1995), I provide plots of these measures from 1990 onward to highlight the large divergence of core inflation from headline inflation early in this period..
[20] When a distribution is asymmetric, the median will differ from the mean. The cross-sectional distribution of component price changes in the PCE index is typically left-skewed, so that the median is typically above the mean.

If trimmed mean and median always consider the entire set of components in any month, why do they depart from headline inflation over 10-year periods? The source of the overall upward bias in median PCE inflation versus headline inflation, and of the time variation in the trimmed mean PCE and median PCE deviations from headline PCE inflation, is slowly varying (and generally negative) skewness across the growth rates of the components in the PCEPI; see Carroll and Verbrugge (2019) for discussion and evidence. Because this is the source of the bias, bias correction for these measures can be accomplished as follows. First, estimate the relationship between asymmetry and bias for the given index. Second, in the current month, compute a 30-month projection of the asymmetry. Third, take an average of the past 30 months and the projected future 30 months; this is an estimate of asymmetry of the five-year centered moving average. Finally, apply the bias correction based on the estimated relationship between asymmetry and bias. For core PCE, bias correction could proceed somewhat similarly, but rather than being based solely on asymmetry and recent bias, it should instead be based on recent bias and on (weighted) recent and projected relative price movements.

Other Considerations

One goal of this paper is to compare core PCE to two other simple trend inflation measures: trimmed mean PCE and median PCE. In this section I collect some previous findings from the literature that are relevant for this comparison.

Reflecting the entire inflation experiences of households. Both the trimmed mean PCE and median PCE inflation measures take into account the entire household budget, since both are efficient estimates of the central tendency of the *entire* price distribution. None of the cross-sectional price information is ignored. Conversely, because it removes two major chunks of the typical household budget, energy and food, core PCE inflation does not fully reflect the inflation experiences of households. Hence, focusing on this measure risks Fed credibility, if it is perceived to be systematically ignoring those prices that households frequently observe and that feature prominently in household budgets (Bullard 2011).

Efficiency/precision in estimating average inflation. Studies of the cross-sectional distribution of price changes using both US data and data from other countries almost invariably show excess kurtosis (see Roger (2000) and the papers cited therein). The sample mean is a measure of the central tendency that is heavily influenced by outliers; intensive work in the field of statistics over the 20th century demonstrated that the sample mean is thus a *very poor estimator* of the central tendency for any other distribution than the Normal distribution (see, e.g., Andrews et al. 1972 or Prescott and Hogg 1977). Regarding core PCE, realizations of changes in food and energy prices are not always outlying, and other components can also end up far in the tails of the distribution in any given month. Since the underlying data do have heavy tails, and since (as noted above) *many* of the items in the index can experience sharp price changes, it immediately follows that (as pointed out more than two decades ago by Bryan and Cecchetti (1994), and demonstrated via simulation in Bryan, Cecchetti, and Wiggins (1997)) the sample mean is not an efficient estimator of the central tendency of inflation, and one can obtain a far more accurate reading of that central tendency using the sample median or a trimmed mean. Thus, both median PCE inflation and trimmed mean PCE inflation put the notion of "removal of volatile components" and "efficient estimation of the central tendency of inflation at any given moment" on a far more solid statistical footing. See Roger (2000) for more discussion. In other words, these measures

arguably more accurately answer the question "what was inflation last month?" than does headline PCE itself.

Tracking of ex-post trend inflation. Three different ex-post inflation trend estimates are a centered 5-year moving average,[21] the Survey of Professional Forecasters' median 5-year forecasts, and a 36-month trimmed mean moving average.[22] Table 4 reports the RMSE of each measure against each of these trend estimates. Trimmed mean PCE outperforms core PCE against the SPF 5-year, ties it against the 36-month trimmed moving average, and is only a whisker behind core PCE against the 5-year MA. Median PCE performs a little worse against all three.[23] This criterion does not clearly favor any of the three measures, reflecting the fact that each measure has time-varying bias.

	RMSE versus five-year MA, 1987:7-2017:6	RMSE versus SPF 5-year, 2007-2019	RMSE versus 36-month trimmed MA, 1986:7-2018:6
Core PCE	0.39 ppts	0.44 ppts	0.41 ppts
Trimmed Mean PCE	0.40 ppts	0.37 ppts	0.41 ppts
Median PCE[24]	0.42 ppts	0.51 ppts	0.49 ppts

Table 4. Source: SPF, BEA via Fred, Federal Reserve Board, Federal Reserve Bank of Cleveland, author's calculations.

Which series adjusts to close the gap? As Eric Rosengren, president of the Boston Fed, pointed out in 2019, when core PCE and trimmed mean PCE inflation diverge, it is core PCE that adjusts to eliminate the gap (Rosengren 2019). The same is true of core PCE vis-à-vis median PCE. This suggests that trimmed mean and median are a more reliable guide to the trend in inflation. Table 5 below presents evidence based upon a regression of quarterly (annualized) inflation rates and the respective core PCE gaps. The adjustment parameter of core against trimmed mean gap is -0.37, and against median gap is -0.31; conversely, neither trimmed mean nor median is influenced by its respective gap.

[21] Numbers are almost identical if the trend estimate from a two-sided HP-filtered quarterly headline PCE inflation is used. The HP filter is a fairly good bandpass filter; having said that, two-sided filtering should be used with caution (see Ashley and Verbrugge (2009, 2020) and Ashley, Tsang, and Verbrugge (2020).

[22] Instead of taking the mean over 36 months, I drop the highest and lowest observation and take the mean over the remaining 34 observations. I do this because a moving average, being an average, is overly sensitive to outliers.

[23] Columns 1 and 3 refer to monthly inflation, while column 2 refers to quarterly inflation. Other research has noted that core PCE can occasionally edge out either trimmed mean or median PCE for a particular trend estimate or time period; see Dolmas (2005), Rich and Steindel (2007), and Carroll and Verbrugge (2019). Over this period, on an ex-post basis, one can select an alternative core basket that removes 15 items and that attains an RMSE versus 5-year MA of 0.32. This basket removes most of energy, but also commodities such as life and health insurance, air transportation, hotels and motels, and jewelry.

[24] We apply a fixed -0.5 percentage points bias adjustment to the median PCE prior to subsequent analysis.

	Dependent Variable			
	Core PCE	Trimmed Mean PCE	Core PCE	Median PCE
constant	0.46*	0.49***	0.48*	0.56***
s.e.	0.27	0.13	0.28	0.16
lag 1 of dependent variable	0.46***	0.48***	0.45***	0.48***
s.e.	0.14	0.07	0.14	0.05
lag 2 of dependent variable	0.24***	0.28***	0.27***	0.24***
s.e.	0.09	0.04	0.07	0.06
lag 1 of gap	-0.37**	0.07	-0.31**	0.06
s.e.	0.16	0.07	0.13	0.06

Table 5. Adjustment of core PCE inflation to trimmed mean PCE inflation or to median PCE inflation

To give some idea of the dynamics following a shock, starting from the steady state, if trimmed mean PCE rises by 0.5 percentage points for two quarters, core PCE inflation will rise by about 0.2 percentage points over the next four quarters. If trimmed mean PCE inflation rises by 0.5 percentage points permanently, core PCE inflation will rise by 0.28 percentage points permanently, and the adjustment will be nearly complete after four quarters.[25]

Forecasting evidence. It is often believed that core PCE inflation has an edge in forecasting, as indicated by Crone et al. (2013). The more recent consensus in the literature is that the forecasting evidence is mixed, and relative performance depends on time period, specification, and forecast evaluation period (see Carroll and Verbrugge 2019, Dolmas and Koenig 2019, and Luciani and Trezzi 2019 for recent studies, and the Appendix for earlier studies).[26] Thus, the forecast evidence does not clearly favor any of the measures. (In any case, for forecasting purposes, there are a wide variety of models to choose from; so forecasting ability only serves to provide a means of comparison across alternative trend inflation measures.)

Cyclicality. Core PCE is less cyclical (and harder to predict) than are trimmed mean or median. Why should we care? For at least two reasons. First, as Dolmas and Koenig (2019) note, policymakers

[25] I am indebted to Cleveland Fed President Loretta Mester (private communication) for prompting this investigation.
[26] Detmeister (2012) performed a search over a wide range of exclusion indexes. Out of sample, these did not outperform core PCE and performed worse than trimmed means. He further notes that instability in the covariance of inflation rates across items suggests that an exclusion approach is unlikely to be a fruitful method for creating a superior trend inflation measure. Earlier, Smith (2007) considered a range of measures built up from components, and explored their relative performance in forecasting headline PCE inflation. There is abundant evidence that the median CPI outperforms the core CPI in forecasting; see, e.g., Meyer, Venkatu, and Zaman (2013) and the Appendix.

sometimes draw inferences about slack from the behavior of inflation. These inferences are only reliable if there is a strong relationship between inflation and labor-market slack. Second, arguably *for monetary policy considerations* it is preferable to have a measure of trend inflation that is more cyclically sensitive, since (according to the prevailing New Keynesian theory of monetary policy) a central bank exerts influence over inflation via its influence over real activity; hence, cyclically sensitive inflation is the part of inflation over which the central bank has more influence. (The Federal Reserve Bank of San Francisco publishes a cyclical core PCE inflation series. For related research, see Shapiro 2018, Stock and Watson 2019, Tallman and Zaman 2017, and Zaman 2019[27]). Furthermore, as Ball and Mazumder (2019) and Ashley and Verbrugge (2020) demonstrate, both median PCE inflation and trimmed mean PCE inflation are well-explained using a Phillips curve relationship.[28] Finally, as Dolmas and Koenig (2019) note, both trimmed mean inflation and median inflation give a more prominent role to "sticky" prices.[29]

Storytelling.[30] It is always possible to indicate which components are responsible for any movement in core PCE inflation, and to assess (or "tell a story") about the likely transience or persistence of that particular price movement. Whether or not such storytelling is truly helpful in communications with the public is debatable: The use of median or trimmed mean removes perceived subjectivity about the role of "special factors" influencing various components at various points in time.

Simplicity and age. Core PCE has admirable simplicity, but so does median PCE inflation ("we just pick the one in the middle"). Admittedly, trimmed mean PCE inflation is a tad more difficult to explain, but it is still simple. While it is true that "core" measures have been in use for a longer period, the median CPI was invented almost three decades ago (Bryan and Pike 1991), and over the ensuing decades this measure (and its cousin, the trimmed mean CPI) have been repeatedly shown to dominate core CPI over many criteria.

Conclusion

The rationale for core PCE inflation is the removal of volatile components that suffer from transitory shocks. On this basis, whether one is concerned about monthly inflation, 12-month inflation, or 5-year inflation, the core basket is outdated. Furthermore, the items removed also have persistent trend – so that core PCE has a significant time-varying bias – and many items that remain are also highly volatile and experience large shocks. Occasionally, these items move sharply in a direction at odds with the remaining items, causing core PCE to give a misleading picture of trend inflation.

Two other prominent trend inflation measures, trimmed mean PCE inflation and median PCE inflation, gracefully address the outdated basket issue and more adequately reduce volatility. Could they replace

[27] Earlier studies include Hubrich (2005), Bryan and Meyer (2010), and Peach, Rich, and Linder (2013). The Federal Reserve Bank of San Francisco has now incorporated the suggestions of Zaman (2019) and uses finer level detail in its routine reporting of cyclical and acyclical indicators.
[28] Ashley and Verbrugge (2020) further demonstrate that their model generates an accurate conditional recursive forecast of trimmed mean PCE inflation dynamics over the Great Recession, and that the Phillips curve has not weakened at all. It is preferable to have a trend inflation measure whose relationship with slack is stable over time.
[29] See Aoki (2001) for the rationale for stabilizing sticky prices.
[30] I am indebted to Alan Detmeister for pointing this out (private communication).

core PCE's focal role? Higgins and Verbrugge (2015b) – building upon Clark (2001), Silver (2007), and Rich and Steindel (2007) – offer five criteria on which a focal trend inflation indicator should be judged: transparency of construction; timeliness (computable with little delay); unbiasedness; not volatile; and historical ability to track the underlying inflation trend. Of these, the first two criteria are met equally by all three measures. Of the last three, core PCE has a more serious time-varying bias, is more volatile, and is not quite as good at tracking the underlying inflation trend. Furthermore, core PCE does no better as a forecasting tool, is less cyclical and thus less reliable as an aid to assessing the state of the labor market, and occasionally gives rise to a highly misleading signal. I conclude that, for a variety of considerations that are relevant for monetary policy deliberations and communication, either trimmed mean PCE inflation or median PCE inflation should replace core PCE inflation as the focal measure of trend inflation.

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Appendix

CPI forecast studies

Among studies using US data, Smith (2004) found that weighted median inflation performs better than consumer prices excluding food and energy at predicting future inflation, both in-sample and out-of-sample. Similarly, Meyer and Pasaogullari (2010) found that either the trimmed mean CPI or inflation expectations from the Survey of Professional Forecasters generally were better predictors of future CPI inflation than the CPI excluding food and energy. Additional studies with US data that compare consumer price inflation excluding food and energy to other inflation indexes include Bryan and Cecchetti (1994), Cecchetti (1997), Freeman (1998), Clark (2001), Robalo Marques, et al. (2003), Clinton (2006), Brischetto and Richards (2007), Bryan and Meyer (2011), and Meyer and Venkatu (2014).

PCE forecast studies

Detmeister (2011) found that PCE inflation excluding food and energy performed worse at matching a handful of ex-post PCE inflation benchmarks than a number of alternative approaches to core inflation. [31] Smith (2012) demonstrated that the trimmed mean PCE was superior to core PCE in forecasting PCE inflation..

Weights have changed a lot since 1985

Figure 1 below depicts changes in aggregation weights in the PCE index since 1985. In particular, for each component I form the ratio of the weight in 2019 to the weight in 1985. Then I plot the histogram of these ratios. The figure indicates, for example, that 13 percent of the categories had an aggregation weight in 2019 that was only 0.65 of its value in 1985; nearly 40 percent of categories experienced declines of this size or larger. [32] Two of the five components whose weight declined most over the period are new domestic autos and new foreign autos. While it is not surprising that "film and photographic supplies" also makes this list, perhaps surprisingly, another member of this list is "audio discs, tapes, vinyl, and permanent digital downloads." (Narrowly missing this list were "repair and hire of footwear" and "clothing repair, rental and alterations.") Meanwhile, the five categories that have seen the most growth in the household budget are, in order: "computer software and accessories"; "used light trucks"; "motor vehicle leasing"; "telephone and related communication equipment" and "personal computers/tablets and peripheral equipment." Other major changes in inflation dynamics stem from technological changes in production processes and from the increased percentage of goods that are manufactured or assembled abroad.

[31] The alternative approaches to PCE inflation examined by Detmeister (2011) included various exclusion indexes, trimmed mean and weighted medians, variance-weighting inflation, weights based on regression coefficients, cost of nominal distortions weighting (CONDI), trend inflation from Stock and Watson's UCSV model, Michigan inflation expectations, and component smoothing.

[32] We do not observe much bunching around 1, the number that corresponds to no change in weight. Only seven categories experienced weight changes that were less than 5 percent over this period.

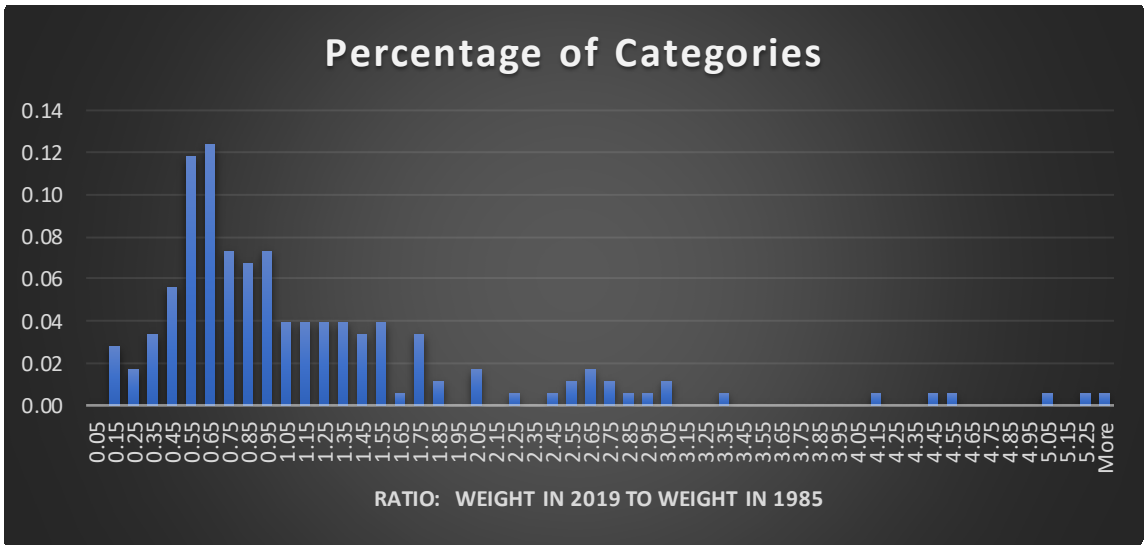

Figure 1. Source: BEA, author's calculations.

On a five-year basis, removing items increases MSE against headline inflation