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Is it Time to Reassess the Focal Role of Core PCE Inflation in Assessing the Trend in PCE Inflation?

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Abstract

"Core" PCE inflation—that is, inflation in PCE-ex-food-and-energy—is widely used as an estimate of trend inflation. But it is long overdue for replacement. The original rationale of core inflation was to remove volatile items with transitory shocks. But aside from gasoline, the list of excluded items is far from optimal. Core inflation also suffers from other severe deficiencies, common to all exclusion indexes. Excluded items often have persistent trends; thus excluding them imparts a significant time-varying bias. Items that are not excluded can experience high volatility, and will cause exclusion indexes to depart notably from trend inflation—as core PCE has done at crucial moments. Two other prominent trend inflation measures, trimmed mean PCE inflation and median PCE inflation, gracefully address these issues (though neither is perfect). A wide variety of evidence comparing these three trend measures is provided. The findings indicate that, for a variety of considerations that are relevant for both trend inflation estimation and for monetary policy deliberations and communication, either trimmed mean PCE inflation or median PCE inflation are superior measures.

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1. Introduction

As is well known, headline inflation measures are highly volatile and subject to sharp transitory movements. This gives rise to demand for inflation trend estimates, that is, estimates that attempt to strip out this transitory noise and provide a better signal of what inflation is likely to be going forward. While sophisticated trend estimates exist (see, e.g., Mertens, 2016), "core" inflation measures—that is, "less-food-and-energy" measures—remain the most popular estimates. As an estimate of the trend in the personal consumption expenditures price index (PCEPI, henceforth PCE), core PCE is in widespread use in academic studies (e.g., Clark and Doh, 2014; Watson, 2014; Nakata, 2017; Bils et al., 2018). Private forecasting firms, such as IHS Markit and Macropolicy Perspectives, provide forecasts and discussion of both headline and core inflation measures, suggesting wide demand among financial market participants for these forecasts.

And while the US Federal Open Market Committee (FOMC) targets 2 percent inflation in headline PCE inflation, core PCE inflation plays a focal role in monetary policy deliberations and communication (see, e.g., Yellen, 2017). Publicly available Tealbooks indicate that, internally, core PCE plays a prominent role in the Fed staff's framework for forecasting all-items inflation. Externally, the FOMC gives public prominence to the core measure through its quarterly Summary of Economic Projections (SEP)—where all FOMC members are asked to provide forecasts for core inflation in addition to all-items inflation, presumably indicating their role in policy discussions—and in its Monetary Policy Reports to Congress. FOMC communications often reference core PCE inflation; for instance, the February 2020 Monetary Policy Report[1] 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.[2]

This paper demonstrates that it is time to reassess the focal role of core PCE inflation—both as an estimate of trend inflation more broadly, and in monetary policy deliberations and communication. Core PCE has some severe deficiencies, and superior alternatives exist. In particular, two simple and robust measures of trend inflation, trimmed mean PCE (Dolmas, 2005) and median PCE (Carroll and Verbrugge, 2019), are either equally good or clearly superior

[1] See https://www.federalreserve.gov/monetarypolicy/2020-02-mpr-summary.htm.

[2] Other central banks make use of exclusion-based indexes, even as official inflation targets. Since 2017, the Sveriges Riksbank has used as its target a CPI that removes the influence of mortgage interest rates. The Czech Republic targets inflation less regulated prices and indirect taxes. Most central banks, such as the European Central Bank, discuss both headline and core HICP inflation in their communications. However, internationally, focus on core inflation measures has been declining over time. For instance, the Bank of Canada officially acknowledges a collection of core measures (trimmed mean, median, common component, etc.) but no longer uses exclusion-based measures in its official set of such "core" inflation measures. Prior to 2004, the UK targeted the RPIX, the Retail Price Index minus mortgage interest payments, but currently gives no official status to any core measures. And prior to 2014, Thailand targeted an ex-food-and-energy index, but currently its target is specified in terms of headline inflation.

along the relevant dimensions of comparison—including for use in the important area of monetary policy communications (see, e.g., Coibion et al., 2021; Binder, 2021). The surge in inflation in the post-COVID environment, which has raised many new questions about the inflation process and renewed interest in alternative trend inflation measures, underscores this conclusion.

Both of these alternative series start in 1977, and are available at the monthly frequency. Each month, median PCE inflation is formed as the weighted median of the underlying inflation components that comprise the PCE; in other words, the median PCE "picks the one in the middle." Trimmed PCE inflation is a weighted trimmed mean of the inflation components; after dropping 24% from the lower tail of the distribution, and 31% from the upper tail, the weighted mean of the remaining components is formed. (See Appendix A for more details.) Owing to the way that extreme inflation realizations of *any* PCE components are trimmed away, both measures are robust statistical estimates that are not influenced by the outliers that prove so troublesome for both headline and core PCE.

This study compares the relative performance of core PCE, trimmed PCE, and median PCE over the 1985–2019 period. It demonstrates that trimmed PCE and median PCE are either equally as good as, or superior to, core PCE along the relevant dimensions.[3] Among the advantages of these measures, they do not suffer from "fixed basket" deficiencies, they more adequately remove volatility, and they provide a better signal of trend inflation. Both are on a much firmer statistical basis. Of course, as would be expected in simple trend inflation estimates, both are imperfect. Like Core PCE, they are also subject to time-varying bias (though arising from a different source, time-varying skewness); and along some dimensions, performance is merely on par with core PCE. Further, both are constructed by regional Federal Reserve Banks, rather than by official statistical agencies. Despite this, an abundance of evidence, both theoretical and empirical, indicates that either of these alternatives would better serve the purposes for which core PCE is currently being employed.

Core PCE no longer deserves the prominence it enjoys, and it is long overdue for replacement. At a minimum, academic studies should use either median PCE, trimmed PCE, or both alongside core PCE. And since both measures are simple to explain but nonetheless summarize the entire inflation experiences of households, are more accurate in real-time, are more cyclically sensitive, and serve as "anchors" to which core PCE returns, either measure would better serve in a focal role in monetary policy deliberations and in policy communication.[4]

2. A Brief History of Core Inflation

Monthly inflation rates are highly volatile, so that it is difficult to tell what a given monthly reading portends for the future. Core inflation—that is, inflation in a "less-food-and-energy" price

[3] 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,b). Summary statistics and more complete descriptions are provided in Appendix A.

[4] Another recent paper on this topic is Dolmas and Koenig (2019). Luciani and Trezzi (2019) are less critical of core PCE.

index—was invented as a simple and practical method to allow people to discern the underlying trend in inflation.

Why is inflation so volatile? Monthly movements in the "headline" personal consumption expenditures price index (hereafter, headline PCE) and in the "headline" consumer price index (hereafter, headline CPI) are computed using a weighted average[5] of the average cost or price changes of numerous components (such as gasoline, college tuition, fresh produce, and men's shoes). Sample averages are very sensitive to outlying observations. Owing to this sensitivity, both of these headline inflation measures are volatile, often moving sharply on a monthly basis (or even on a 12-month basis) because a few important components experience very large shocks. Since these large shocks often revert, their impact on headline inflation obscures the underlying trend in inflation. To better identify that trend, one would like to strip out large, transitory shocks.

During the 1970s, large oil price shocks and volatile movements in food prices caused a lot of volatility in headline inflation, 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.[6] The core CPI is constructed in the same way as headline CPI, except it simply excludes most food and energy items, and increases the aggregation weights of the remaining items. Removal of food and energy 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.[7] 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.[8] In this article, I re-evaluate core PCE from several perspectives.

Given the preponderance of evidence indicating that the inflation process changed markedly

[5]A given component's aggregation weight corresponds to its importance in the consumption basket of a typical consumer.

[6]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. Gordon (1975) was the first to analyze core inflation in a systematic manner. 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 Wynne (2008) provide more details about the history of core inflation and the development of alternative measures of trend inflation, including the history of the term "core inflation," which came into use in the early 1980s.

[7]"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.

[8]For more details about how the PCE index and CPI index differ, see Binder et al. (2020).

in the mid-1980s, the sample period begins in 1985. And since I do not want conclusions to be driven by the unusual behavior of inflation over the course of the pandemic recession and early recovery, the sample ends in 2019. Thus over the 1985–2019 period, the paper compares the behavior of three indexes: core PCE, trimmed PCE and median PCE.

3. Deficiencies in Core PCE

This section covers three notable deficiencies in core PCE.

3.1 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 et al., 2020) and the global economy is much more integrated. Most studies find that the Phillips curve weakened considerably in the early 1980s (see, e.g., Blanchard, 2016). And there have been major changes in available goods and services and in preferences.

Partly 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 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 Appendix C): 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 over the post-1985 period (column 1), and also compute the volatility of the same items over the 1985–2004 and post-2005 periods.[9] This ranking ignores the contributions of covariance, but gives a sense in which various items contribute to the volatility of headline PCE inflation. Items in bold face are excluded from core PCE. Notice that only six of the items that are excluded from core PCE make this top-15 list. Gasoline is very volatile and

[9] The "volatility" of an index is measured as its standard deviation. I compute $w_i \sigma_i$ where w_i is component i's average aggregation weight over the period (1985–2005, 2005–2019, or 1985–2019), and σ_i is the monthly standard deviation of the annualized growth rate of that component. Life insurance is a special case. It is omitted from the Table 1: owing to two outliers associated with the September 11th attacks, it is the second most volatile item (at 0.59) over the 1985–2019 period. After removing these outliers, its weighted volatility is 0.03 over the entire period. Motor vehicle and other transportation insurance is also omitted, owing to several extreme outliers in 1985. From 1985–2019, its weighted volatility is 0.20. From 1986–2019, its weighted volatility is 0.10. One could make the case that outliers should be included, since other components are likely to experience extreme outliers in the future. No attempt has been made to formally identify outliers. In this univariate context, formal outlier identification could proceed using standard tools; but in multivariate data, using recently developed tools such as Garciga and Verbrugge (2021) puts the analysis on a much firmer statistical footing.

Table 1

Top-15 components in the PCE price index, ranked by weighted volatility.

Weighted volatility, 1985–2019	Weighted volatility, 1985–2004	Weighted volatility, 2005–2019	PCE Component
1.53	**1.13**	**2.02**	**Gasoline and other motor fuel**
0.34	0.33	0.29	Financial service charges, fees, and commissions
0.22	0.26	0.17	Air transportation
0.21	0.21	0.20	Final cons. expenditures of nonprofits institutions serving households
0.20	0.22	0.16	Women's and girls' clothing
0.19	0.21	0.13	Owner-occupied stationary homes
0.18	**0.19**	**0.17**	**Natural gas**
0.18	**0.23**	**0.11**	**Tobacco**
0.16	0.16	0.12	Nonprofit hospitals' services to households
0.16	**0.21**	**0.08**	**Vegetables (fresh)**
0.15	0.15	0.14	Commercial banks
0.15	0.13	0.16	Physicians' services
0.14	**0.14**	**0.13**	**Electricity**
0.12	0.14	0.10	Fuel oil
0.12	0.14	0.06	Net health insurance

Note: Items in bold are excluded from core PCE.
Source: BEA, author's calculations.

has a relatively large weight, so its weighted volatility is the largest, by far.[10] But the next 5 most volatile items are all *included* in core PCE.[11] Among these top 15, the sum of the weighted volatility of items included in core PCE is nearly as large (90 percent) as that of the items excluded from core. Hence, from a "reducing volatility" perspective—the reason core inflation was invented—the core PCE basket appears to leave much to be desired.

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.[12] 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.[13] But monthly volatility

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

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

[12]Furthermore, when an item is removed, all remaining weights need to be increased, so that the weights still sum to one.

[13]As in footnote 11 above, I treat life insurance and motor vehicle insurance differently. In Table 1, for each series, I winsorize the outliers, replacing the negative extreme outliers with the 1st percentile value of the series, and the extreme positive values with the 99th percentile. After winsorizing, neither component makes it into Tables 1 or 2. 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

Table 2

Reduction in volatility from sequential removal of various components of PCE, by measure of volatility, ranked.

	Monthly		12-month		5-year	
Volatility of headline PCE		2.282		1.074		0.71
	component	reduction	component	reduction	component	reduction
	Gas	**0.978**	**Gas**	**0.237**	NonPr hosp	0.072
	Fin srvcs	0.040	NonPr hosp	0.066	Phys srvcs	0.045
	Air trans	0.034	Phys srvcs	0.037	**Gas**	**0.046**
	Nat gas	**0.026**	Gov hosp	0.017	Gov hosp	0.023
	W clothes	0.020	Computers	0.016	Computers	0.017
	NonPr hosp	0.020	**Fuel Oil**	**0.013**	Health ins	0.016
	Jewelry	0.020	Games	0.013	Games	0.014
	Fresh Veg	**0.018**	Health ins	0.010	Prop hosp	0.014
	Phys srvcs	0.019	Telephone	0.010	Para med	0.012
	Fuel oil	**0.035**	Prop hosp	0.009	Telephone	0.011
	Comput.soft	0.011	TVs	0.008	TVs	0.011
	Household linen	0.011	Jewelry	0.008	Software	0.009
	Electricity	**0.011**	Software	0.008	Tobacco	0.008
	Telephone	0.010	**Nat gas**	**0.008**	Sport goods	0.008
	Computer	0.009	Luggage	0.007	Luggage	0.007

Note: Items in bold are excluded from core PCE. Abbreviations: Air trans: air transportation; Computers: personal computers/tablets and peripheral equipment; Comput.soft: computer software and accessories; 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; Luggage: luggage and similar personal items; Nat gas: natural gas; NonPr hosp: nonprofit hospitals' services to households; Para med: paramedical services; Phys srvcs: physician services; Prop hosp: proprietary hospitals; Software: computer software and accessories; Sport goods: Sporting equipment, supplies, guns, and ammunition; Telephone: telephone and related communication equipment; TVs: televisions; W clothes: Women's and girls' clothing.
Source: BEA retrieved via Haver Analytics, author's calculations.

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 in bold face are excluded from core inflation.

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 only a scant resemblance to the rankings here. Even if one were concerned only with monthly volatility, only 5 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 horizons. Fourth, for five-year volatility, gasoline ranks third. This

inflation from 1.09 to 1.20.

implies that not only does gasoline experience some shocks that are very short-lived (e.g., a hurricane knocks out some refineries for a couple of months), but it also experiences longer-lived shocks (e.g., the collapse of oil prices around 2014–2016). Persistent shocks are not the sorts of shocks that core inflation was intended to remove. I return to this observation in Section 3.3. In short, by any of these metrics, the core basket is outdated.[14]

3.2 Core Inflation is Sensitive to Outliers, and is thus Volatile

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 the center of the distribution, 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.

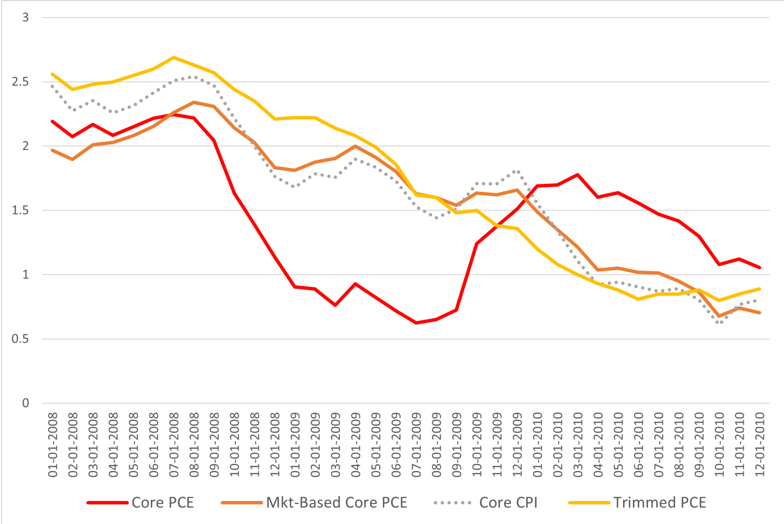
When a component is dropped, the aggregation weight on all remaining components rises. This means that core inflation is even *more* sensitive than headline inflation to outlier observations in the *remaining* components. This sensitivity is reflected in the volatility that remains in core inflation. 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.[15]) 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 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.

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. Other trend indicators, *including core CPI inflation*, fell more slowly, experienced little or no rebound, and continued to decline until late 2010. (A

[14]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 footnote 33. In terms of the impact on volatility at various horizons, see also Dolmas (2009), who explores how various exclusions impact the "cyclical" component estimated from a band-pass filter, and how they impact the ability to forecast headline inflation at various horizons.

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



Source: BEA and BLS, retrieved via Haver Analytics, and Federal Reserve Board.

Figure 1. Anomalous movement of core PCE inflation over the Great Recession and early in the recovery.

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.[16,17]

Because volatile items remain in the core PCE basket, core PCE movements are quite volatile compared to two other simple trend inflation measures, trimmed PCE inflation and median PCE inflation.[18] This sensitivity makes it more volatile than the two alternative measures of trend inflation considered here. From 1985–2019, 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 PCE and for median PCE. It may also be responsible for the reversion-to-trimmed-mean (or median) behavior of core PCE outlined in Section 4.4.

[16] 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.

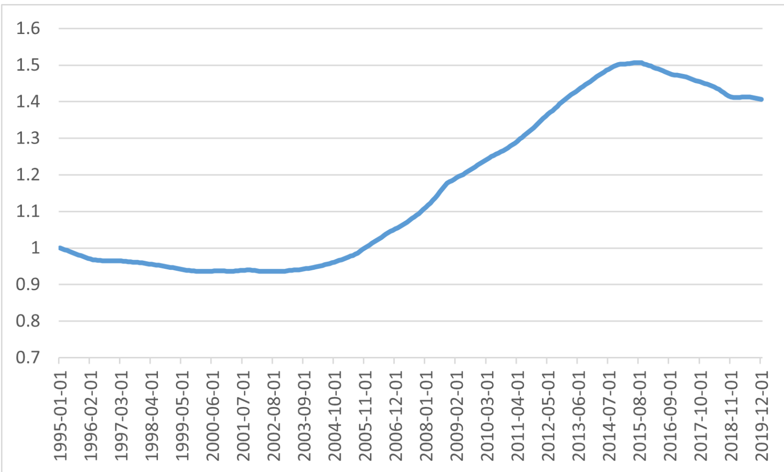
[17] A referee pointed out that this episode is also an interesting illustration of the "data-revisions" deficiency of core PCE; I discuss this in Section 4.8 below.

[18] 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 entered with their full weight into the core PCE in April, but did not influence trimmed PCE and median PCE in April.

3.3 Relative Price Movements, Skewness, and Bias

A third deficiency in the core PCE basket stems from persistent relative price movements of excluded items.[19] Perhaps the most important of these relates to energy. To highlight how energy can experience persistent relative price movements from time to time, 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 1995–2019, with this ratio normalized to 1 in January 1995. 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 2003 and 2015, the relative price of energy rose by over 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.[20]

But the other measures considered in this study are also biased.[21] To investigate the 10-year



Source: BEA retrieved via Haver Analytics, author's calculations.

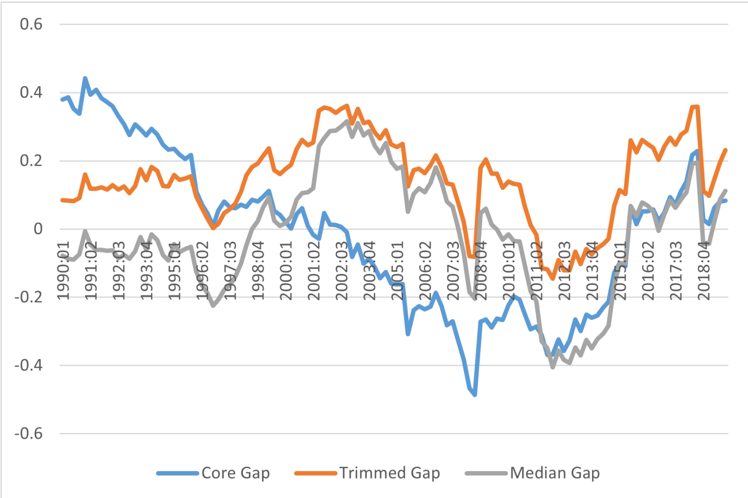
Figure 2. Ten-year moving average of the relative price of energy.

[19] Dolmas (2009) also calls attention to this problem. He first notes that excluded items may feature sustained relative price trends. He uses a frequency-based approach, and notes that the most problematic items are those that are important in the index and that have high power across both high and low frequencies. See also Giri (2021).

[20] 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. See also Bradley et al. (2015) and Giri (2021) for similar conclusions about the deficiency of core CPI.

[21] Note that in this definition of bias, headline PCE is taken as the reference. But one can make the case that headline PCE is a rather deficient measure of the center of the inflation distribution each month; see section 4.2.

bias in core PCE and to compare it to the bias in two other simple trend inflation measures, trimmed PCE and median PCE, I analyze rolling 40-quarter-mean of core PCE, trimmed PCE, median PCE, 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 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 that is suggested by Carroll and Verbrugge, 2019) minus the 10-year average of quarterly PCE inflation. I plot these in Figure 3.[22] It is evident that at various times, such as the early 1990s and from mid-2006 through mid-2011, the 10-year bias of core PCE inflation exceeds that of the other two trend inflation measures. And as Carroll and Verbrugge (2019) point out, the standard deviation of the bias of core PCE greatly exceeds that of the other two measures; a trend estimate with stable bias is preferable to one with a lot of time variation in that bias.



Source: BEA retrieved via Haver Analytics, Federal Reserve Board, Federal Reserve Bank of Cleveland, author's calculations.

Figure 3. Time-varying differential of trend inflation measures against headline PCE inflation, 10-Year moving averages of quarterly data.

Table 3
Differential versus headline inflation over 10-year horizons.

	RMSE of 10-year MA vs headline PCE, 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 PCE	0.20 ppts	0.36 ppts	0.15 ppts	0.51 ppts
Median PCE	0.19 ppts	0.31 ppts	0.41 ppts	0.72 ppts

Source: BEA retrieved via Haver Analytics, Federal Reserve Bank of Cleveland, Federal Reserve Bank of Dallas, author's calculations.

[22]The fact that core inflation bias averages out over *very long* periods of time is not very relevant.

How closely do each of these measures adhere to headline inflation over 10-year horizons? Various metrics are presented in Table 3. Over the 1995–2019 period,[23] on a 10-year centered moving-average basis, median PCE inflation (after applying the 0.5 percentage points *fixed* bias adjustment[24]) was slightly closer to headline inflation on average—its RMSE was 0.19, versus 0.20 for both of the other measures. Trimmed PCE inflation had a far smaller *range* of bias (column 4) and is arguably thus favored by this criterion. Of course, comparisons of this sort are sensitive to the metric and the time period under consideration; see Rich and Steindel (2007). For instance, consider the RMSE versus headline over the full historical range of (10-year MA of) trim PCE and median PCE data (i.e., 1987 onwards). Over this period, core PCE had an RMSE of 0.22 vs. headline, trimmed PCE had an RMSE of 0.18, and median PCE had an RMSE of 0.19. As a second example, suppose we simply looked at bias between 2000 and 2015. Considering 12-month averages, trimmed PCE averaged a 0.08 ppt upward bias versus headline PCE, median PCE (without bias adjustment) averaged a 0.37 ppt upward bias, and core PCE averaged a 0.17 ppt downward bias.

If trimmed PCE and median PCE always consider the entire set of components in any month—and are thus insensitive to relative price movements—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 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.[25] For a more thorough discussion (and weighted skewness formulas, and evidence), see Carroll and Verbrugge (2019) and Verbrugge and Zaman (2022). But to summarize the argument, if a distribution is negatively skewed, its median will be greater than its mean; and the bigger the skew, the bigger the gap. Hence as skewness in the underlying distribution of PCE components varies over time, so too will the bias of median PCE and trimmed PCE.

Owing to this source of the bias for these two measures, real-time bias correction for these measures (say, over a centered 5-year horizon) could be accomplished as follows. First, for a given index, construct five-year centered moving averages of bias and of weighted robust asymmetry. Second, using these moving averages, estimate the relationship between asymmetry and bias for that index. Third, construct an estimate of the *current* centered five-year estimate of asymmetry. To do so, in the current month, construct a 30-month projection of the asymmetry. Then append this projection to the average of the past 30 months, to obtain a five-year window (30 months of data, 30 months of projections). This is an estimate of the five-year centered moving average

[23] Because inflation dynamics changed markedly in the early 1980s, the earliest data in the formal comparison begin in 1985. Thus 10-year averages begin in 1995. However, it is instructive nonetheless to provide a plot of these measures from 1990 onward, to demonstrate how core inflation has diverged widely from headline inflation in both directions.

[24] As discussed immediately below, median PCE is systematically above the mean. The other two measures are not bias-adjusted, since the trimmed PCE is designed to be unbiased, and core PCE is usually treated as unbiased.

[25] Using the conventional measure (normalized third central moment), skewness estimates are typically *positive*. However, moment estimates are dominated by outliers. Robust skewness measures indicate that the distribution is typically negatively skewed.

of asymmetry. Finally, apply the bias correction based on the estimated relationship between asymmetry and bias.[26,27] Of course, any such procedure will be subject to errors, and lead to data revisions.[28]

One could also bias-correct core PCE (although this would violate the spirit of that measure). For core PCE, owing to its source—relative price movements of excluded items—bias correction for core PCE would proceed on a somewhat different basis. In this case, one would need to construct a 30-month projection of the weighted relative price. Next, one would compute the average weighted relative price over the past 30 months and projected future 30 months, and construct a bias correction (based upon the current aggregation weight of a given component in headline PCE) on this basis.

4. Other Criteria

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

4.1 Reflecting the Entire Inflation Experiences of Households

Both the trimmed 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.[29] 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 (Mishkin and Schmidt-Hebbel, 2002; Bullard, 2011).

[26] Rich et al. (2001) provide a related approach, based upon a 12-month moving average of asymmetry. After debiasing Median PCE and Trimmed PCE using their approach, 10-year RMSEs (see Table 3) fall to the 0.11-0.12 range, and the 10-year time-varying differentials (with rare exceptions) remain in the (-0.2,+0.2) range for both measures.

[27] This suggestion is related to a trimming-selection procedure offered by Roger (1997) and adopted by Bryan and Cecchetti (2001). These authors suggest selecting a percentile of the distribution (not necessarily the median) about which to trim symmetrically, as follows. Begin by noting that the median PCE trims symmetrically about the 50th percentile of the data. In the presence of asymmetry in the distribution, this leads to a biased estimate of the mean. Instead, select an alternative percentile of the distribution, about which to trim symmetrically. This "mean percentile" is chosen such that the resulting trimmed estimator is unbiased on average, over some relevant period (such as the last ten or twenty years). In principle, in account for time-varying asymmetry, one could select a new mean percentile every month, based on a smaller window of past data.

[28] One could alternatively conduct a one-sided asymmetry adjustment, which would increase errors but would eliminate the need for revisions. One can also imagine a hybrid approach, in which on an annual basis (say), historical data would be revised to receive a two-sided adjustment. This would be similar to how seasonal adjustment is done for the CPI.

[29] Bryan and Cecchetti (2001) state it this way: "...once we systematically alter the market basket in this way, we are no longer measuring a representative expenditure-weighted cost of living statistic...the resulting aggregate price change answers a fundamentally different question than the [headline measure was] designed to do."

4.2 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 Bryan and Cecchetti, 2001 and 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). And in the presence of both kurtosis and asymmetry, the performance of the sample mean is even worse. Now consider core PCE. This is a weighted mean over all components except food and energy components. But 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 feature both asymmetry and 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 et al., 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 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 two measures arguably more accurately answer the question "what was inflation last month"? than does headline PCE itself. Conversely, the same cannot be said about core PCE, given its susceptibility to outliers and its omission of energy and food (see Sections 3.2 and 3.3 above).

4.3 Tracking of Ex-Post Trend Inflation

A trend inflation measure should reliably signal the trend in inflation. Historically, how do these measures compare with one another? To answer this question, one must first ascertain the "true" trend in inflation. However, even after the fact, this trend must still be estimated. There are numerous candidates, but three different ex-post inflation trend estimates that have been used in previous research are a centered 5-year moving average,[30] the Survey of Professional Forecasters' median 5-year forecasts (which start in 2007), and a 36-month trimmed mean moving average.[31] Table 4 reports the RMSE of each measure against each of these trend estimates, over

[30] Centered or lagged moving averages are often used as estimates of trend inflation (see, e.g., Brayton et al., 1999), although some use bandpass-filtered data (e.g., Dolmas, 2005). The Table 4, Column 1 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, 2021 and Ashley et al., 2020) if said estimates are used as regressors.

[31] It is becoming increasingly common to use the inflation expectations of professional forecasters as an estimate of trend inflation (see, e.g., Dolmas, 2005; Faust and Wright, 2013; Clark, 2014). Cecchetti (1997) and Dolmas (2005), among others, used a 36-month moving average. Instead of taking the mean over 36 months, I compute a trimmed mean. I drop the highest and lowest observation, and take the mean over the remaining 34 observations. The rationale is that a moving average, being an average, is overly sensitive to outliers.

Table 4
RMSE of trend inflation measures versus ex-post trend estimates.

	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 PCE	0.40 ppts	0.37 ppts	0.41 ppts
Median PCE	0.42 ppts	0.51 ppts	0.49 ppts

Source: SPF, BEA retrieved via Haver Analytics, Federal Reserve Bank of Dallas, Federal Reserve Bank of Cleveland, and author's calculations.

the post-1985 period whenever possible.[32] Trimmed 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.[33]

While median PCE performs a tad worse, this criterion does not clearly favor any of the three measures, reflecting the fact that each measure has time-varying bias (see Section 3.3). But there are two other reasons to suspect that core PCE is a less reliable signal of trend inflation than are trimmed PCE or median PCE. The first reason is discussed next; the second is discussed in section 4.4 below.

Mertens (2016) is a sophisticated attempt to estimate trend inflation, and his results—which are decidedly less favorable to core PCE—provide a complementary perspective on the trend in inflation. His approach estimates trend inflation based upon a broad information set that includes headline and core PCE inflation, trimmed PCE inflation, and inflation expectations from surveys (including the SPF). The relevance of each individual indicator variable—i.e., its weight or Kalman gain—is also estimated. Mertens compares various models, such as models based only upon headline PCE and core PCE, models based only upon trimmed PCE,[34] models based only upon surveys, models based only upon financial market variables, and models which combine two or more of these groups of variables. When the trimmed PCE is added to an inflation-measures-only model, it receives almost all of the weight; the weight placed upon all other measures, including core PCE inflation, becomes negligible. Further, in a forecast comparison, the trend estimate based only upon trimmed PCE inflation outperformed the trend estimates from all other models—including models based upon surveys, and models including core PCE inflation—except at short horizons. Mertens concludes: "...the trimmed-mean rate of PCE inflation stands out as a particularly good signal of trend inflation."

[32] As above, I apply a fixed -0.5 percentage points bias adjustment to the median PCE prior to this analysis. Five-year-ahead forecasts of PCE inflation are only available in the SPF starting in 2007.

[33] 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 PCE 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 health insurance, air transportation, hotels and motels, and jewelry.

[34] Trimmed inflation models also include median CPI inflation and trimmed mean CPI inflation, but these measures receive negligible weight. Median PCE was not available at the time this study was conducted.

4.4 Which Series Adjusts to Close the Gap?

Presumably, if core PCE is a better signal of trend than (say) trimmed PCE, then when trimmed PCE diverges from core PCE, trimmed PCE should subsequently adjust to eliminate the gap. But as Eric Rosengren, then president of the Boston Fed, pointed out in 2019, when core PCE and trimmed PCE inflation diverge, it is core PCE that adjusts to eliminate the gap (Rosengren, 2019). Below, I conduct a similar analysis and reach the same conclusion; moreover, I find that 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.

To investigate this hypothesis, I use specifications motivated by error-correction equations. Let π_t^{core} denote quarterly (annualized) core PCE inflation, let π_t^{trim} denote quarterly trimmed PCE inflation, and let π_t^{med} denote quarterly median PCE inflation. (Also, define $\Delta\pi_t^{core} = \pi_t^{core} - \pi_{t-1}^{core}$, and define $\Delta\pi_t^{trim}$ and $\Delta\pi_t^{med}$ similarly.) For investigating the dynamic relationship between core PCE and trimmed PCE, we use the following specification:

$$\begin{aligned} \pi_t^{core} &= \alpha^{core} + \beta_1^{core}\pi_{t-1}^{core} + \beta_2^{core}\pi_{t-2}^{core} + \lambda^{core}\left(\pi_{t-1}^{core} - \pi_{t-1}^{trim}\right) + u_t^{core} \\ \pi_t^{trim} &= \alpha^{trim} + \beta_1^{trim}\pi_{t-1}^{trim} + \beta_2^{trim}\pi_{t-2}^{trim} + \lambda^{trim}\left(\pi_{t-1}^{core} - \pi_{t-1}^{trim}\right) + u_t^{trim} \end{aligned} \tag{1}$$

We use a similar specification for the core PCE-median PCE relationship:

$$\begin{aligned} \pi_t^{core} &= \alpha^{core} + \beta_1^{core}\pi_{t-1}^{core} + \beta_2^{core}\pi_{t-2}^{core} + \lambda^{core}\left(\pi_{t-1}^{core} - \pi_{t-1}^{med}\right) + u_t^{core} \\ \pi_t^{med} &= \alpha^{med} + \beta_1^{med}\pi_{t-1}^{med} + \beta_2^{med}\pi_{t-2}^{med} + \lambda^{med}\left(\pi_{t-1}^{core} - \pi_{t-1}^{med}\right) + u_t^{med} \end{aligned} \tag{2}$$

The penultimate term in each equation (i.e., the term $\left(\pi_{t-1}^{core} - \pi_{t-1}^{trim}\right)$ in Equation (1)) is the gap between the two inflation series. Consider the relationship between core PCE and trimmed PCE. If core PCE adjusts to eliminate the gap, then we would expect λ^{core} estimate to be negative and statistically significant; if trimmed PCE adjusts to eliminate the gap, then we would expect the λ^{trim} estimate to be positive and statistically significant. If they both move to close the gap, both would be significant.

Table 5 below presents the regression results. The adjustment parameter of core against the trimmed PCE gap is -0.37, and against the median PCE gap is -0.31; conversely, neither trimmed PCE nor median PCE is influenced by its respective gap. (We also investigated specifications in $\Delta\pi_t^{core}$, $\Delta\pi_t^{core}$, and $\Delta\pi_t^{core}$; these specifications and results are given in Appendix D. Conclusions are unchanged.)

To give some idea of the dynamics following a shock, starting from the steady state, if trimmed 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 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.[35]

[35] I am indebted to Cleveland Fed President Loretta Mester (private communication) for prompting this investigation.

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

	Core vs. Trimmed PCE Equation (1)		Core vs. Median PCE Equation (2)	
	Core PCE	Trimmed PCE	Core PCE	Median PCE
α	0.46*	0.49***	0.48*	0.56***
	(0.27)	(0.13)	(0.28)	(0.16)
β_1	0.46***	0.48***	0.45***	0.48***
	(0.14)	(0.07)	(0.14)	(0.05)
β_2	0.24***	0.28***	0.27***	0.24***
	(0.09)	(0.04)	(0.07)	(0.06)
λ	−0.37**	0.07	-0.31**	0.06
	(0.16)	(0.07)	(0.13)	(0.06)

Note: This table contains the results of least squares estimation of Eq. (1) and (2) in the text. The dependent variables are listed in column headings. Estimation is over 2005–2019. Reported in parentheses are HAC standard error estimates (using 2 lags). (***, **, *) indicate significance at the 1%, 5% and 10% level.
Source: BEA retrieved via Haver Analytics, Federal Reserve Bank of Dallas, Federal Reserve Bank of Cleveland, and author's calculations.

4.5 Forecasting Evidence

It is often believed that core PCE inflation has a modest edge in forecasting, on the basis of studies such as Crone et al. (2013). But the consensus in the recent literature is that the forecasting evidence is decidedly mixed, and relative performance depends on time period, specification, and forecast evaluation period (see Carroll and Verbrugge, 2019, Dolmas and Koenig, 2019, Luciani and Trezzi, 2019, and Verbrugge and Zaman, 2022 for recent studies, and Appendix B for earlier studies).[36] Thus, the forecast evidence does not clearly favor any of the measures.

4.6 Cyclicality

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

[36] Detmeister (2012) performed a search over a wide range of exclusion indexes. Out of sample, these alternatives did not outperform core PCE, but 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 et al. (2013) and the studies noted in Appendix B.

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, 2020; Tallman and Zaman, 2017; and Zaman, 2019[37]). Furthermore, as Ball and Mazumder (2020) and Ashley and Verbrugge (2021) demonstrate, both median PCE inflation and trimmed PCE inflation are well-explained using a Phillips curve relationship.[38] Finally, as Dolmas and Koenig (2019) note, both trimmed PCE inflation and median PCE inflation give a more prominent role to "sticky" prices.[39]

4.7 Storytelling (And its Motivation)[40]

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 PCE or trimmed PCE both removes the influence of unusually large movements in various components, and removes perceived subjectivity about the role of "special factors" influencing those various components at particular points in time.

4.8 Revisions and Real-Time Accuracy

Inflation data are subject to revisions that can be sizable (see Knotek and Zaman, 2017). But revisions to core PCE tend to be much larger on average than revisions to trimmed PCE. Dolmas (2019) demonstrates that in 90 percent of the months from 2005 to May 2019,[41] revisions to trimmed PCE are less than 0.2 percentage points in absolute value; conversely, core PCE revisions exceeded 0.2 percentage points in about 40 percent of months (and there were a few months where revisions exceeded 0.7 percentage points).

During the Great Recession, as discussed above, core PCE displayed anomalous and misleading behavior (see Figure 1). What is also true about this episode is that the core PCE path was sharply revised. In particular, the first 12-month inflation reading for December 2009 (released on February 1, 2010) was 1.45 percent. But the August release provided a sharply different picture. December 2009 inflation now read 1.77 percent. Readings for other months changed even more. For instance, the March 2010 reading increased nearly 0.5 percentage points, from 1.32 percent (May release) to 1.76 percent (August release). Conversely, while the trimmed PCE path was also revised upwards in August, its biggest revision was +0.22 percent (for the February

[37] Earlier studies include Hubrich (2005), Bryan and Meyer (2010), and Peach et al. (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.

[38] Ashley and Verbrugge (2021) further demonstrate that their model generates an accurate conditional recursive forecast of trimmed PCE inflation dynamics over the Great Recession and recovery, and that the Phillips curve did not weaken in the early 2000s. It is preferable to have a trend inflation measure whose relationship with slack is stable over time.

[39] See Aoki (2001) for the rationale for stabilizing sticky prices.

[40] I am indebted to Alan Detmeister for pointing this out (private communication).

[41] Real-time data are not available to compute this type of estimate prior to 2005.

and March readings).

Trimming the most extreme price changes leads to less susceptibility to revision, since bigger revisions tend to occur in more volatile series. For this reason, median PCE will share this smaller-revisions property. A series with smaller revisions provides a more accurate real-time signal.

4.9 Simplicity and Age

Core PCE has admirable simplicity, but so does median PCE inflation ("we just pick the one in the middle"). Admittedly, trimmed 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.

5. Conclusion

Core PCE enjoys a prominence in both academic studies and in monetary policy deliberation and communication. The rationale for core PCE inflation is the removal of volatile components that suffer from transitory shocks. But 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. And core PCE is often subject to quite large revisions, reducing its real-time accuracy.

Two other prominent trend inflation measures, trimmed PCE inflation and median PCE inflation, gracefully address the outdated basket issue, more adequately reduce volatility, are subject to smaller revisions, and are arguably better signals of trend inflation. Should one of them replace 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 as good at tracking the underlying inflation trend—it plays little role in sophisticated attempts to estimate the inflation trend (Mertens, 2016) and when it departs from trimmed PCE (or median PCE), it is the measure that adjusts to eliminate the gap. 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, is subject to larger revisions, and occasionally gives rise to a highly misleading signal. I conclude that core PCE no longer deserves the prominence it enjoys in academic studies and in monetary policy communications and deliberation. For inflation trend estimation more broadly, and for a variety of considerations that are relevant for monetary policy deliberations and communication, either trimmed PCE inflation or median PCE inflation would better serve in a focal role than core PCE.

Of course, neither of these alternative measures is perfect. Perhaps the most prominent deficiency is time-varying bias. Owing to persistent fluctuations in skewness of the inflation distribution, trimmed PCE and median PCE have persistent fluctuations in bias against headline PCE inflation. This paper suggested a method for undertaking bias adjustment in real time. But one might argue that it would be better to construct a new simple trend inflation estimator that was designed to be unbiased, perhaps using a modification of the mean percentile approach referenced in Section 3.3. Such a measure could outperform trimmed PCE and median PCE as trend inflation estimates. Construction of such a measure is beyond the scope of this paper, but would be an interesting avenue for further research.

Appendix A - Description and Summary Statistics of Inflation Measures

Table A.1
Summary statistics: headline PCE, core PCE, trimmed PCE, median PCE.

	availability	average inflation, 1985–2019 (percent)	standard deviation of monthly growth rate, 1985–2019
headline PCE	1959–	2.25	2.34
core PCE	1959–	2.24	1.55
trimmed PCE	1978–	2.33	0.93
median PCE	1978–	2.71	0.96

Source: BEA retrieved via Haver Analytics, Federal Reserve Bank of Dallas, Federal Reserve Bank of Cleveland, and author's calculations.

How are these measures constructed? The description here is taken from Dolmas (2005), pp.4-5 and p.10.

In any given month, the rate of inflation in a price index like the CPI or the PCE can be thought of as a weighted average of the rates of change in the prices of all the goods and services that make up the index. In contrast to the CPI, which uses expenditure weights which remain fixed for two years, the PCE is a chain-aggregate whose weights vary from month to month. While PCE weights are not precisely expenditure shares, they bear a close relationship to expenditure shares.

In particular, to a first approximation, the weight a component receives in this month's PCE is an average of (1) its expenditure share last month and (2) what its expenditure share would be if consumers bought this month's quantities at last month's prices.

Let $\{P_{i,t}, Q_{it}\}_{i=1}^{N}$ denote the list of prices and real quantities for N components at time t. The gross rate of growth in the PCE price index, P_t, from t to $t+1$ obeys the Fisher ideal index formula:

$$\frac{P_{t+1}}{P_t} = \sqrt{\frac{\sum_i Q_{i,t} P_{i,t+1}}{\sum_i Q_{i,t} P_{i,t}} \frac{\sum_i Q_{i,t+1} P_{i,t+1}}{\sum_i Q_{i,t+1} P_{i,t}}}. \tag{A.1}$$

Define the 1-month inflation rates in the overall index and for each of the N component prices in the usual way, by

$$\pi_{t+1} = \frac{P_{t+1}}{P_t} - 1 \quad \text{and} \quad \pi_{i,t+1} = \frac{P_{i,t+1}}{P_{i,t}} - 1.$$

Then (A.2) implies the approximation

$$\pi_{t+1} \cong \sum_i \omega_{i,t+1} \pi_{i,t+1}, \tag{A.2}$$

where

$$\omega_{i,t+1} = \frac{1}{2} \frac{Q_{i,t} P_{i,t}}{\sum_i Q_{i,t} P_{i,t}} + \frac{1}{2} \frac{Q_{i,t+1} P_{i,t}}{\sum_i Q_{i,t+1} P_{i,t}}. \tag{A.3}$$

That is to say, the PCE inflation rate in any given month is a weighted average of the rates of change of the constituent components, with weights, given by (A.3), that vary over time. An item's weight may be loosely referred to as its "share" in the PCE, though one should bear in mind that this is only half true (literally). As (A.3) shows, a component's weight at date $t+1$ is an average of its expenditure share at t and what it's share would be, hypothetically, if consumers bought $t+1$'s quantities at t's prices.

The trimmed PCE and median PCE are constructed using (A.2), except that: a) the list of items I included in (A.2) is reduced, and b) the weights used are accordingly adjusted so that the sum of the weights totals to 1.

More precisely, let $\{(\omega_{i,t}, \pi_{i,t}) : i = 1, 2, ..., N\}$ denote the distribution of component price changes from a given month, and reorder the N components such that $\pi_{1,t} \leq \pi_{2,t} \leq ... \leq \pi_{N,t}$. We choose a lower trim α and an upper trim β. Thus choose $0 < \alpha < \beta < 1$, and let $\hat{i}_t(\alpha) = min\left\{I : \sum_{i=1}^{I} \omega_{i,t} \geq \alpha\right\}$ and $\hat{i}_t(\beta) = max\left\{I : \sum_{i=I}^{1} \omega_{i,t} \leq \beta\right\}$. Thus we include all items such that the corresponding weight cut from the lower (left) tail is "close" to β, and the weight cut from the upper (right) tail is "close" to α. Then the (α, β)-trimmed mean PCE at date t is defined by

$$\pi_t^{(\alpha,\beta)} = \frac{1}{1-\alpha-\beta} \sum_{i=\hat{i}_t(\alpha)}^{\hat{i}_t(\beta)} \omega_{i,t+1} \pi_{i,t+1}.$$

The median is formed this way as well, with $\alpha = 49.9$ and $\beta = 49.9$.

12-month inflation rates are calculated as follows. First, one forms an index (one may set the initial value = 100). The index is moved by the inflation rate in the first month. Then in month two, one moves the month-one index by the inflation rate in the second month, and so on. Finally, using the constructed index, one forms the 12-month growth rate. Thus, if π_t is the monthly (non-annualized) growth rate (in percent) of the measure at t, and I_{t-1} is the index at $t-1$, one forms the index at t as

$$I_t = I_{t-1}\left(1 + \frac{\pi_t}{100}\right),$$

and then the 12-month growth rate at time s, π_s^{12}, is given by

$$\pi_s^{12} = 100\left(\frac{I_s}{I_{s-12}} - 1\right).$$

Appendix B - Forecast Studies

Appendix B.1 - 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).

Appendix B.2 - PCE Forecast Studies

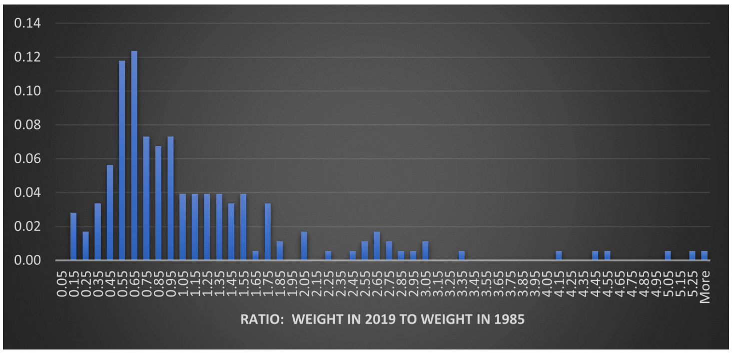
Detmeister (2011) found that PCE inflation excluding food and energy performed worse at matching a handful of ex-post PCE inflation benchmarks than a number of alternative approaches to core inflation.[42] Smith (2012) demonstrated that the trimmed PCE was superior to core PCE in forecasting PCE inflation.

Appendix C - Weights Have Changed a Lot Since 1985

Figure C.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.[43] 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.

[42] 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.

[43] 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.



Source: BEA retrieved via Haver Analytics, author's calculations.

Figure C.1. Percentage of categories.

Appendix D - Alternative Specification for Error-Correction Regressions

Specifications in $\Delta\pi_t^{core}$, $\Delta\pi_t^{trim}$, and $\Delta\pi_t^{med}$: for the core PCE-trimmed PCE relationship,

$$\begin{aligned}\Delta\pi_t^{core} &= \alpha^{core} + \beta_1^{core}\Delta\pi_{t-1}^{core} + \beta_2^{core}\Delta\pi_{t-2}^{core} + \lambda^{core}\left(\pi_{t-1}^{core} - \pi_{t-1}^{trim}\right) + u_t^{core} \\ \Delta\pi_t^{trim} &= \alpha^{trim} + \beta_1^{trim}\Delta\pi_{t-1}^{trim} + \beta_2^{trim}\Delta\pi_{t-2}^{trim} + \lambda^{trim}\left(\pi_{t-1}^{core} - \pi_{t-1}^{trim}\right) + u_t^{trim}\end{aligned} \tag{E.1}$$

and for the core PCE-median PCE relationship,

$$\begin{aligned}\Delta\pi_t^{core} &= \alpha^{core} + \beta_1^{core}\Delta\pi_{t-1}^{core} + \beta_2^{core}\Delta\pi_{t-2}^{core} + \lambda^{core}\left(\pi_{t-1}^{core} - \pi_{t-1}^{med}\right) + u_t^{core} \\ \Delta\pi_t^{med} &= \alpha^{med} + \beta_1^{med}\Delta\pi_{t-1}^{med} + \beta_2^{med}\Delta\pi_{t-2}^{med} + \lambda^{med}\left(\pi_{t-1}^{core} - \pi_{t-1}^{med}\right) + u_t^{med}\end{aligned} \tag{E.2}$$

Table D.1 below presents the regression results. In this error-correction specification as well, we see that core PCE adjusts to eliminate the gap in either case.

Table D.1
Adjustment of core PCE inflation to trimmed PCE inflation or to median PCE inflation.

	Core vs. Trimmed PCE Equation (E.1)		Core vs. Median PCE Equation (E.2)	
	Core PCE	Trimmed PCE	Core PCE	Median PCE
α	-0.19***	-0.01	-0.06	-0.02
	(0.07)	(0.05)	(0.06)	(0.04)
β_1	-0.67***	-0.48***	-0.68***	-0.50***
	(0.10)	(0.09)	(0.11)	(0.08)
β_2	-0.28***	-0.22**	-0.28***	-0.29***
	(0.09)	(0.09)	(0.09)	(0.09)
λ	-0.73***	0.06	-0.49**	0.09
	(0.26)	(0.12)	(0.19)	(0.11)

Note: This table contains the results of least squares estimation of Eq. (E.1) and (E.2) in section D of the appendix. The dependent variables are listed in column headings. Estimation is over 2005–2019. Reported in parentheses are HAC standard error estimates (using 2 lags). (***, **, *) indicate significance at the 1%, 5% and 10% level.
Source: BEA retrieved via Haver Analytics, Federal Reserve Bank of Dallas, Federal Reserve Bank of Cleveland, and author's calculations.

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