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Abstract

This paper challenges the underlying assumptions that form the basis for current US inflation measurement. Standard inflation models implicitly treat all divergences of sector price changes as temporary noise. Based on this logic, the only force driving price level changes over time must be the underlying inflation rate. This paper proposes an alternative model that allows for persistent sector-specific price changes, and then conducts statistical tests to determine if sector price changes represent significant alternate forces driving measured inflation. The tests show that several sectoral forces are distorting measured inflation, indicating that traditional inflation gauges are not measuring underlying inflation properly for policy purposes. These distortions suggest that the Federal Reserve's decision to announce an explicit 2% inflation target may have been misguided. The 2% target may not be appropriate during times when sector-specific forces are the dominant drivers of measured inflation.

Keywords: inflation, sectoral analysis, consumer price index, inflation measurement, Fed policy, inflation target

Section 1: What is inflation and how do we measure it?

When the subject of inflation comes up, invariably the discussion centers on the standard measures of inflation: the consumer price index (CPI) and the personal

consumption expenditure (PCE) deflator.[1] These measures have become synonymous with inflation in the eyes of the public. However, the concept of inflation is fundamentally different from these measures.

> Inflation is the increase in the general price level over the medium to long term. It is the portion of the rise in goods and services prices that is both *common* to all prices and *persistent* over time.

While the concept of inflation seems straightforward, it is extremely challenging in practice to measure the general price level for everything that is purchased. Economists have wrestled with measuring true underlying inflation for decades. They have found ways to deal with complications such as the weighting and combining of price changes and the accounting for new and substitute products. However, economists have not yet found an inflation measure that truly captures the medium- to long-term concept of changes in the general price level. Real world data exhibit month-to-month fluctuations that are not related to underlying inflation.

How can idiosyncratic short-term fluctuations be separated from common and persistent price changes? There have been many attempts to statistically see through the noise to the underlying inflation path, most of which have entailed modifying the CPI and the PCE deflator by taking out volatile components to isolate "core" measures. The most common adjustment is to exclude food and energy

[1] For a full accounting of the differences between the CPI and the PCE deflator, see McCully, Moyer, and Stewart [2007]. Since the PCE deflator uses the CPI survey as its source data, the analysis in this paper focuses solely on CPI data.

components, because fluctuations in these categories rarely reflect underlying inflation trends. Other methods tried include trimmed-mean and median inflation measures, which minimize the impact of the most extreme sector price changes each month (Bryan and Cecchetti [1994], Cecchetti [1996], Meyer [2013]). Khan, Morel and Sabourin [2013] and Amstad and Potter [2014] present measures of underlying inflation based on factor models.

Economists do not always agree on the best way to gauge the underlying inflation rate. Many modifications of the CPI and PCE deflator are summarized, reviewed and evaluated in Rich and Steindel [2007], who find that price movements are too volatile to make a case for any particular version of core inflation. Kiley [2008] finds that core measures that exclude food and energy are best, while Meyer, Venkatu and Zaman [2013] find the trimmed mean CPI to be most accurate. Wynne [2008] offers a discussion of the goals of inflation measurement and the benefits of using core measures for making policy decisions. Bullard [2011] presents an opposing point of view, arguing that policymakers should focus instead on headline inflation measures, which "were designed to be the best measures of inflation available."

Each of the attempts to measure underlying, common price changes implicitly assumes that variations in sector price changes are short term and random, so they gravitate to zero over time.

This study takes an entirely different approach and challenges the basic assumptions of the standard inflation model. It asks the question: Are individual price changes driven by a single underlying inflation rate as the standard model

assumes, or are there other persistent sector-specific forces driving price changes and distorting measured inflation?

If the latter is true, then all of the current measures of inflation would be flawed. They would be merging sector-specific price changes with underlying inflation. The core measures and factor models purport to take out at least some sector-specific price changes, but they only eliminate short-term fluctuations and shocks, not persistent drivers of price changes. Also, they test their core measures by comparing with other inflation measures that may have the same flaws.

This paper proposes an alternative model that introduces a term for persistent sector-specific price changes, and then tests to see if those price changes exert a significant force on measured inflation. The paper is organized as follows: Section 2 presents the standard and alternative models of inflation, Section 3 reveals that more than half of the sectors in the CPI have been out of sync with the measured inflation rate for extended periods, Section 4 takes a closer look at some key sectors, and Section 5 presents conclusions.

Section 2: Inflation measurement models

Standard model. The traditional model makes the implicit assumption that price movements of every item in the CPI follow the same pattern

$$(1) \quad \pi_i = \pi^* + \mu_i$$

where π_i is the actual price change of product i, π^* is the underlying inflation rate, and μ_i is a catch-all error term that includes random noise and other short-term

fluctuations including relative price shocks. In other words, every price rises with the underlying inflation rate (π^*) modified by idiosyncratic short-term noise (μ_i).[2] This generates a distribution of price increases and decreases. In the end, all prices gravitate to the underlying inflation rate.

Inflation measures such as the CPI, which pool together price changes of all the goods and services consumers purchase into a single weighted average gauge, can be modeled as

$$(2) \quad \sum \pi_i = \pi^* + \sum \mu_i$$

where the sums are weighted averages of all the items in the inflation measure at a given point in time. The term $\sum \pi_i$ is the measured inflation rate, π^* remains the underlying inflation rate common to all prices, and $\sum \mu_i$ represents a weighted average of all short-term fluctuations. According to the central limit theorem, if there are enough prices being measured, the short-term sector-specific μ_i's will approximate a normal distribution and the expected value of $\sum \mu_i$ will be zero. As a result, the measure of inflation ($\sum \pi_i$) will equal the underlying value (π^*) on average.

The problem with this model is the assumption that all sector fluctuations are short-lived and contained in the $\sum \mu_i$ term. The model does not allow for persistent shocks, which introduces a possible bias into inflation measurements.

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[2] Amstad and Potter [2014] used this assumption in creating the FRBNY's inflation gauge, which is designed to capture the underlying persistent inflation rate by looking at wide array of individual prices.

Alternative model. Unlike the assumption in the standard model above that all sector fluctuations are short-lived, this study proposes that persistent sector price changes could exist that are driven by other forces. If that is the case, individual prices may be written as

$$(3) \quad \pi_i = \pi^* + \rho_i + \mu_i$$

where ρ_i represents idiosyncratic persistent price changes in a particular sector.

Under this assumption, inflation measures would combine individual price changes to yield an inflation measure that looks like

$$(4) \quad \sum\pi_i = \pi^* + \sum\rho_i + \sum\mu_i$$

where $\sum\rho_i$ is the weighted average of the effects of all idiosyncratic persistent price changes of individual sectors.

In this model, in addition to the underlying inflation term π^*, there are now two types of idiosyncratic sector price changes: the same short-term noise term ($\sum\mu_i$) as in the standard model, and the new term representing medium- to long-term price changes driven by sector-specific forces ($\sum\rho_i$). Unlike the $\sum\mu_i$ term, there is no reason to expect the value of the persistent sector-specific term $\sum\rho_i$ equals zero.

If $\sum\rho_i$ is zero, then the expected value of Equation 4 would be the same as that of Equation 2 (the underlying inflation rate π^*), and the assumptions of the traditional model would hold. On the other hand, if $\sum\rho_i$ is not zero, inflation measures would be distorted because they would be combining underlying inflation (which they are trying to measure) with sector-specific price changes.

Section 3: Persistent divergence of price changes

The study now tests to see if sector-specific price changes are short-lived random shocks as the standard model assumes, or if sector price changes persist beyond any reasonable definition of short-term. In other words, are the ρ_i terms significant drivers of measured inflation?

To check for persistence, this study compared the price changes from 54 sectors in the CPI against the measured inflation rate for every year going back to 1998.[3] Specifically, the study counted the number of times in the past 19 years that sector prices increased at a faster/slower pace than the core CPI. This is akin to running a 19-flip coin toss experiment 54 times.

If the price fluctuations can be represented by μ_i, alone, they must be short-term, unbiased, and random. That means the number of times sector prices rise faster or slower than the core CPI should be roughly even for most series. The distribution of these relative sector prices changes would look like the gray bars in Figure 1, which represents the probabilities from a 50-50 coin flip example. In contrast, if the sector price changes are persistent and should be represented by ρ_i, the number of times these sector prices rise faster or slower than core CPI should be skewed.

The results were surprising. As the black bars in Figure 1 show, the actual price change data revealed that more than half the values were in the tail regions (less

[3] Source data are from the Bureau of Labor Statistics and Haver Analytics. The study looks at prices changes for all items that have been in the CPI since 1998 – except food products and energy.

than five heads or more than 14 heads at the 1 percent significance level).[4] Specifically, of the 54 observations, 17 were below five and 18 were above 14. These results showed unmistakable evidence that deviations in price changes by sector tend to persist well beyond any reasonable sense of the short term. A binomial exact test on these data rejected the notion that the individual short-term fluctuations were random with 99 percent confidence.

This analysis has demonstrated the persistence of divergent price changes across sectors, suggesting that underlying inflation is not the only long-term driver of price changes. Furthermore, current models are not equipped to separate these persistent sector-specific price changes from the persistent changes common to all prices that defines true underlying inflation.

Section 4: Multiple driving forces

Now the study turns to the question of how and why some prices rise faster or slower than others over prolonged periods. One possibility is the split between goods and services. Are goods and services driven by different forces?

[4] The chart compares two histograms. Gray: The horizontal axis shows the possible number of heads from a hypothetical experiment of flipping a coin 19 times. This experiment is repeated 54 times and the vertical axis shows the number of times the experiment likely would yield each number of heads, based on standard probabilities. Black: The horizontal axis shows the possible number of years that each item's price changes were higher than core CPI. The experiment is repeated for all 54 items. The vertical axis counts the number of items whose price changes exceeded core CPI zero times through 19 times.

Over the past 20 years, services (excluding energy) prices have increased by an average of nearly 3 percent, while goods (excluding food and energy) prices have barely increased at all on average. In fact, goods price increases surpassed services in only one year of the past 20 (Figure 2). Not only are these price changes significantly and persistently different, but goods and services prices are not positively correlated, as you would expect if they were driven by the same force, such as an underlying price level. The correlation coefficient between these two series over this time frame is negative 0.41.

This divergence probably reflects the fact that goods prices are increasingly being determined by the global market. The import content of private domestic demand has increased sharply over the past several decades. In 1970, imports accounted for just 10 percent of private domestic demand, and today that figure is 44 percent. So, the excess global capacity of traded goods could be dampening goods prices. This would explain the lack of price increases over the past two decades, despite the rise in US services prices. It would also explain why these prices do not tend to adjust to the degree of slack in the domestic economy, as the Phillips curve would suggest.

Meanwhile, services by their nature are dependent on domestic pricing conditions, especially labor costs, because labor is the most important input for services. As such, these prices may mostly reflect the rise in the general price level. That may be why recent studies show that services exhibit the strongest Phillips curve tendency.[5]

[5] See Seydl and Spittler [2016].

To see if the divergence between goods and services pricing explains the persistence in the histogram experiments above, the same analysis was performed comparing individual services prices against all services prices (excluding energy) and individual goods prices against all goods prices (excluding food and energy). If the goods/services split explained all of the persistent variations, the phenomenon would disappear when compared with goods and services separately. The results showed that the split between goods and services explained some, but not all, of the persistent variations (Figures 3 and 4). Many items that can be categorized as goods or services followed similar patterns of price changes. However, even when the data were split into goods and services, there were a significant number of observations in the tails.

It turns out that nearly all the remaining outliers were in just three sectors: medical care, education and technology. The fact that these sectors seem to move on their own with independent drivers should not be too surprising. Medical care is largely disconnected from economy-wide drivers because employer-financed health insurance has created a system where medical pricing is not transparent to consumers.[6] Likewise, education costs have skyrocketed as student loans have expanded, allowing colleges to ramp up prices.[7] Finally, technological quality has consistently improved over the past two decades, resulting in steady (quality-

[6] See Reinhart [2013].

[7] See Lucca, Nadauld and Shen [2017].

adjusted) product price declines over the entirety of the tech revolution since the 1990s.[8]

Section 5: What this means for Fed policy

Since monetary policymakers do not have the tools to manage sector-specific price changes, their best course of action would seem to be to conduct policy based on movements in the underlying inflation rate common to all goods and services. But as this paper shows, underlying inflation cannot be separated from persistent sector-specific price changes. A central bank conducting policy toward a specific inflation target using traditional inflation measures as a guide could not be sure that the target was consistent with the desired underlying inflation rate.

By announcing an explicit target of 2%, the Federal Reserve locked itself into policy positions to achieve that goal. However, if the weighted average of persistent sector-specific price changes is significantly positive or negative, the published inflation data may not truly reflect underlying inflation. As a result, Fed policy could end up being persistently too tight or easy.

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[8] The rise in owners' equivalent rent (OER), which comprises nearly 25% of the CPI, has persistently exceeded core CPI increases as well, but the overshoots seem to be explained by the general overshoot of *all* services, as the OER observation in Figure 4 was close to the middle. However, because OER represents such a substantial weight in inflation measures and the divergences have been large, it should be noted that this sector alone can account for a sizable ρi term and distort estimates of π^*.

This study recommends that the Fed should take a more holistic approach to policy, given these newly identified uncertainties surrounding underlying inflation. For example, the Fed would have more flexibility if it targeted an inflation band that was wide enough to encompass a reasonable range of sector-specific price change effects. The course of action would be to keep inflation steady within a band and adjust policy if imbalances begin to develop.

Research extensions. This study has covered a 19-year period in which inflation was modest by historical standards. This analysis could be extended to include a period of generally higher inflation. At high underlying inflation rates, the sector-specific forces could tend to be obscured because common, persistent inflation is the predominant driver of price changes. In those instances, π^* could be more distinguishable from the sector-specific drivers. This could generate a contrast with the results from the low inflation period studied here, where the underlying inflation rate does not dominate as much, and measures of the true underlying inflation are not as clearly defined.

Finally, this paper leaves for further research a new attempt to measure the common underlying inflation rate, based on the alternative inflation model specification, which takes full account of persistent sector-specific price changes.

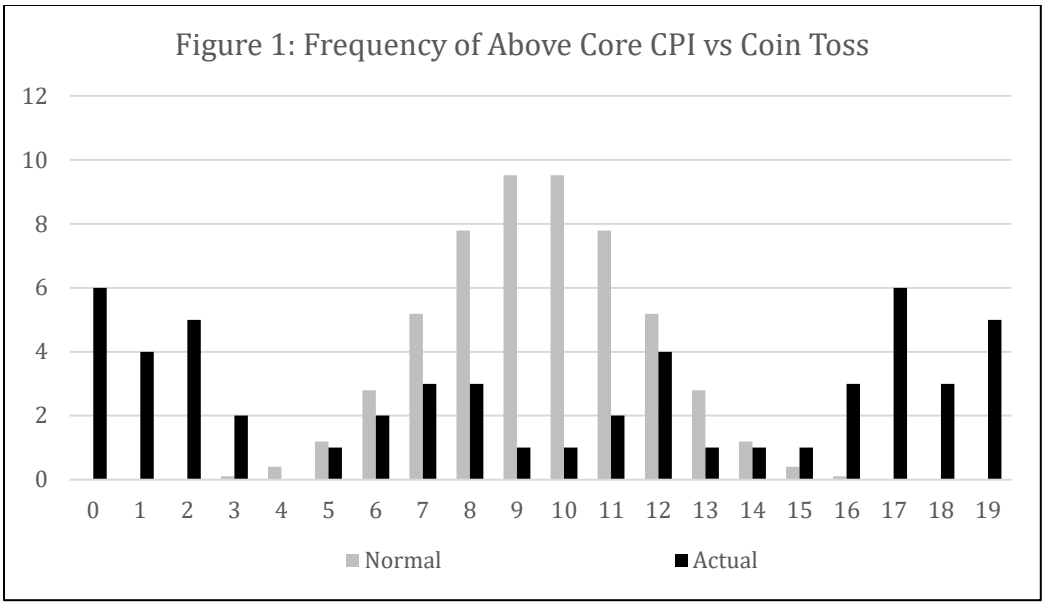
Figure 1: Frequency of Above Core CPI vs Coin Toss
12
10
8
6
4
2
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Normal
Actual

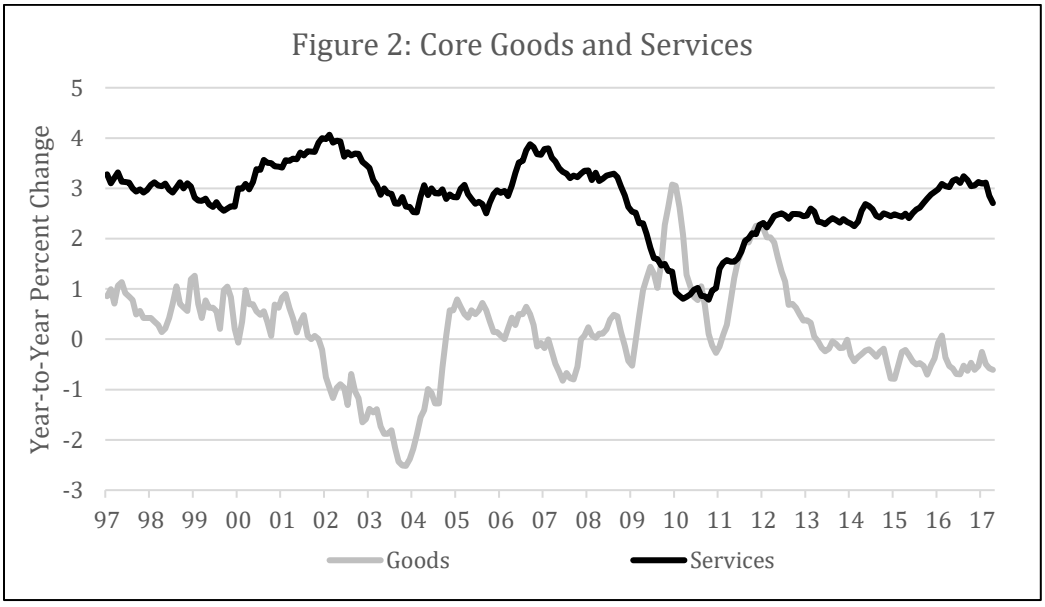
Figure 2: Core Goods and Services
Year-to-Year Percent Change
5
4
3
2
1
0
-1
-2
-3
97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17
Goods
Services

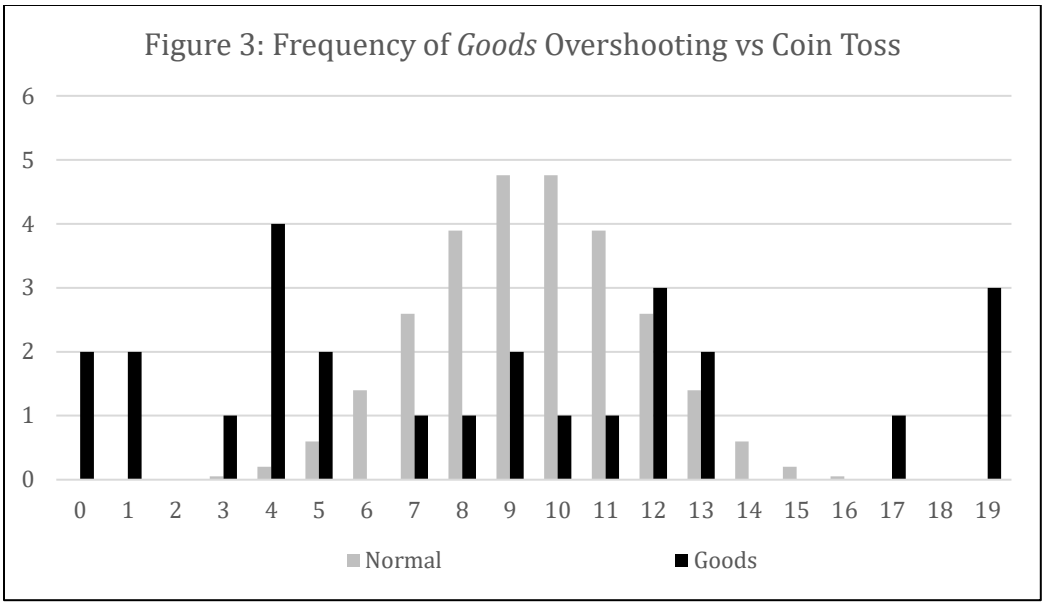
Figure 3: Frequency of *Goods* Overshooting vs Coin Toss
6
5
4
3
2
1
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Normal
Goods

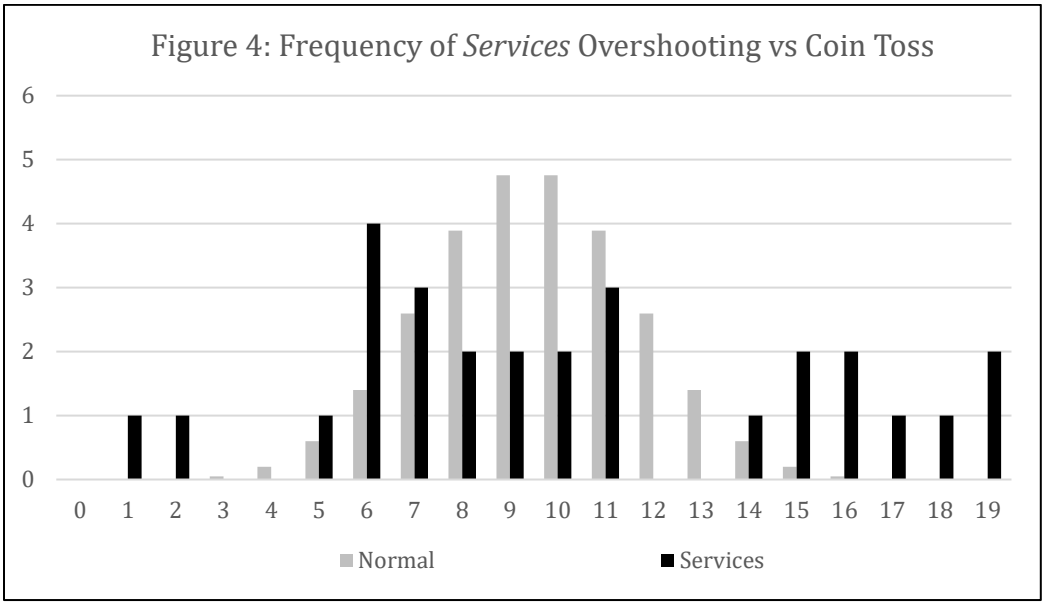
Figure 4: Frequency of *Services* Overshooting vs Coin Toss
6
5
4
3
2
1
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Normal
Services

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