



November 15, 2018

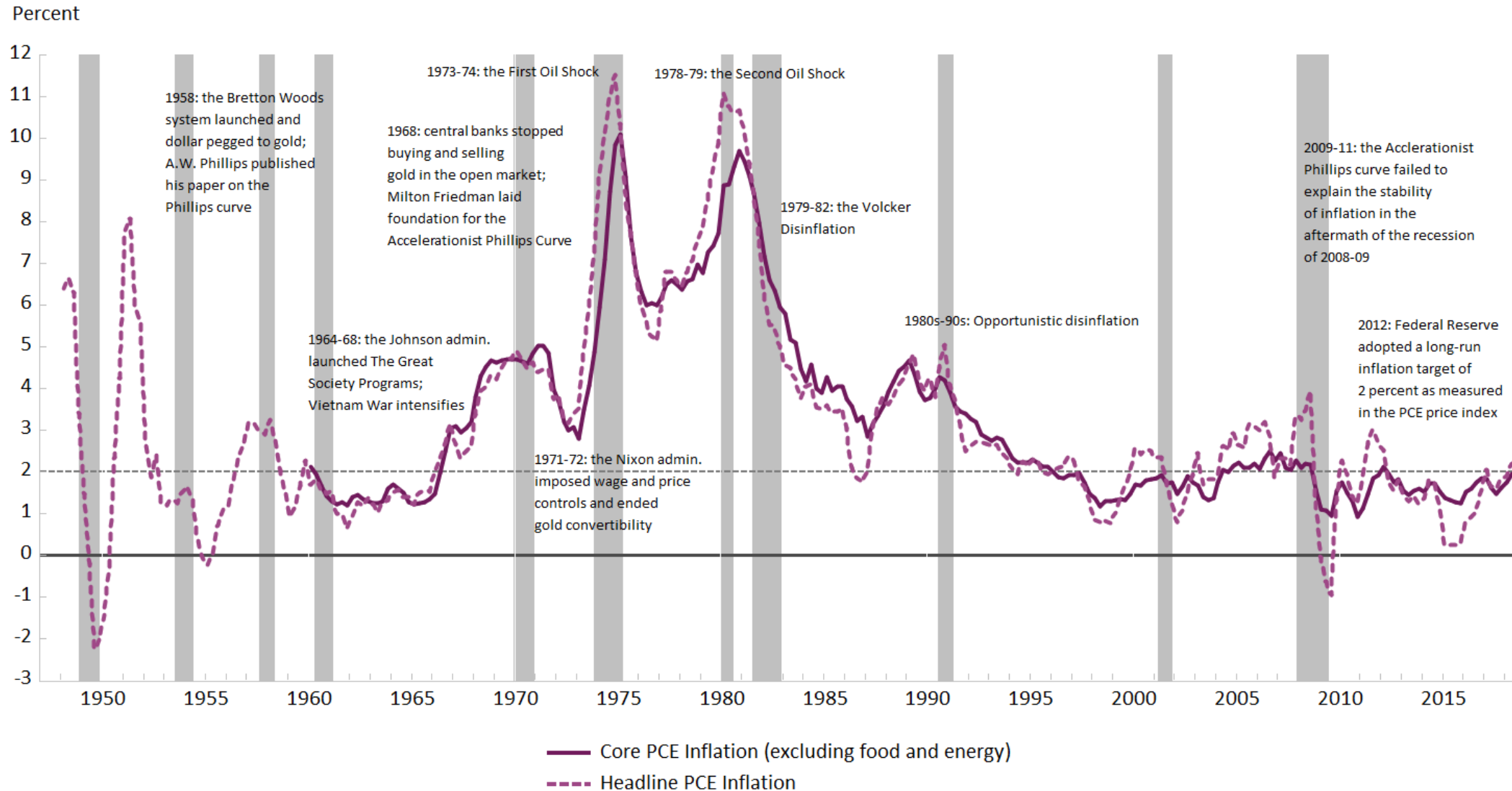
## **Inflation and the Phillips Curve**

66<sup>th</sup> Annual Economic Outlook Conference  
Research Seminar in Quantitative Economics, University of Michigan

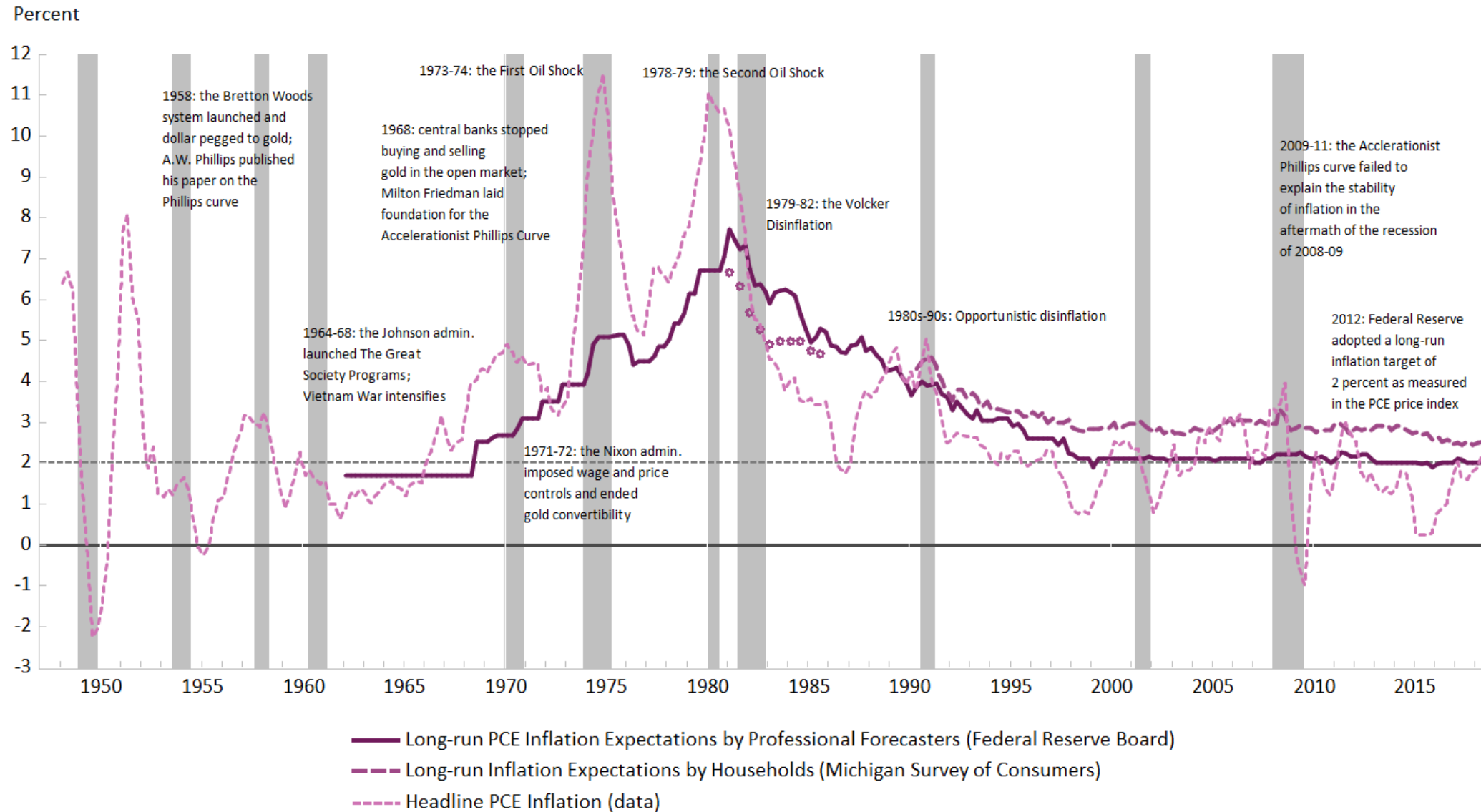
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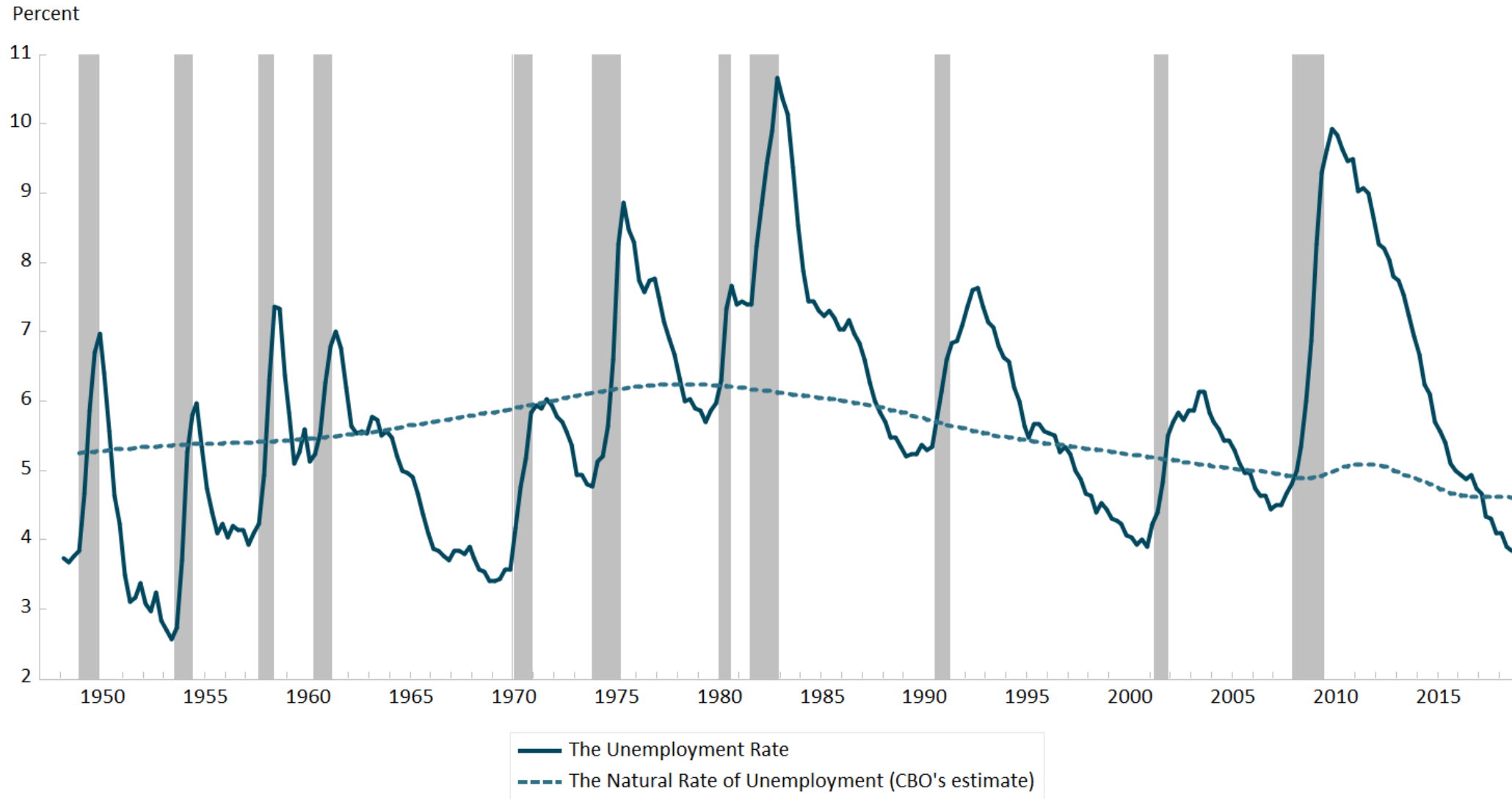
# Inflation: 1948–2018



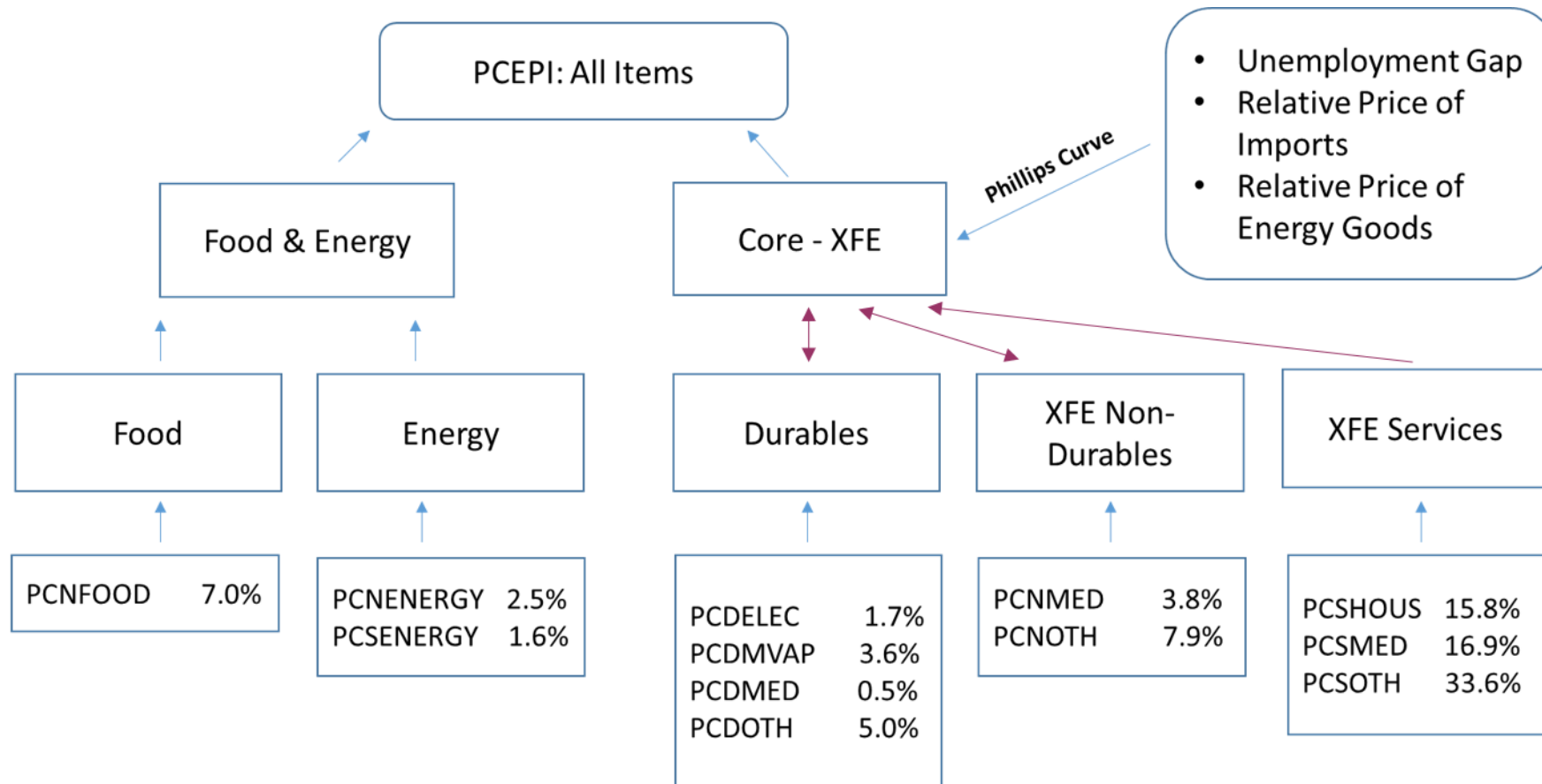
# Inflation Expectations: 1948–2018



# Unemployment: 1948–2018



# Structure of CBO's Model for the Personal Consumption Expenditures (PCE) Price Index



This flow chart shows the structure of CBO's inflation model for the PCEPI, as well as the spending shares for its components. Those components include PCNFOOD: Food & Beverage Purchases for Off-Premises Consumption; PCNENERGY: Gasoline & Other Energy Goods; PCSENERGY: Electricity and Gas; PCDELEC: Video, Audio, Photo & Info Processing Equipment & Media; PCDMVAP: Motor Vehicles & Parts; PCDMED: Therapeutic Appliances & Equipment; PCDOTH: Other Durable Goods (CBO's calculation); PCNMED: Pharmaceutical & Other Medical Products; PCNOTH: Other Nondurable Goods (CBO's calculation); PCSHOUS: Housing; PCSMED: Health Care Services; and PCSOTH: Other Services (CBO's calculation).

# Expectation-Augmented Phillips Curve

$$\pi_t = E_t \pi_{t+1} - \beta(U_t - U^*) + \gamma Z_t + \epsilon_t$$

## ▪ Determinants of inflation

- $E_t \pi_{t+1}$ : Inflation expectations
- $\beta(U_t - U^*)$ : Unemployment gap, or other measures of slack in the economy
- $\gamma Z_t$ : Supply-side shocks (for example, relative price of imports, energy, etc.)

## ▪ Issue 1: Cyclical sensitivity of inflation

- For the price index of personal consumption expenditures (PCEPI) excluding food and energy (“XFE” or “core-XFE”):  $\beta$  has declined from 0.3~0.4 in the 1970s to 0.05~0.1 in the most recent decades.
- Does inflation still respond to slack?

## ▪ Issue 2: The form of inflation expectations

- “Accelerationist”:  $E_t \pi_{t+1} = A(L)\pi_{t-1}$  (distributed lags of inflation)
- “Anchored”:  $E_t \pi_{t+1} = \pi^*$  (constant)
- Combined:  $E_t \pi_{t+1} = \alpha A(L)\pi_{t-1} + (1 - \alpha)\pi^*$

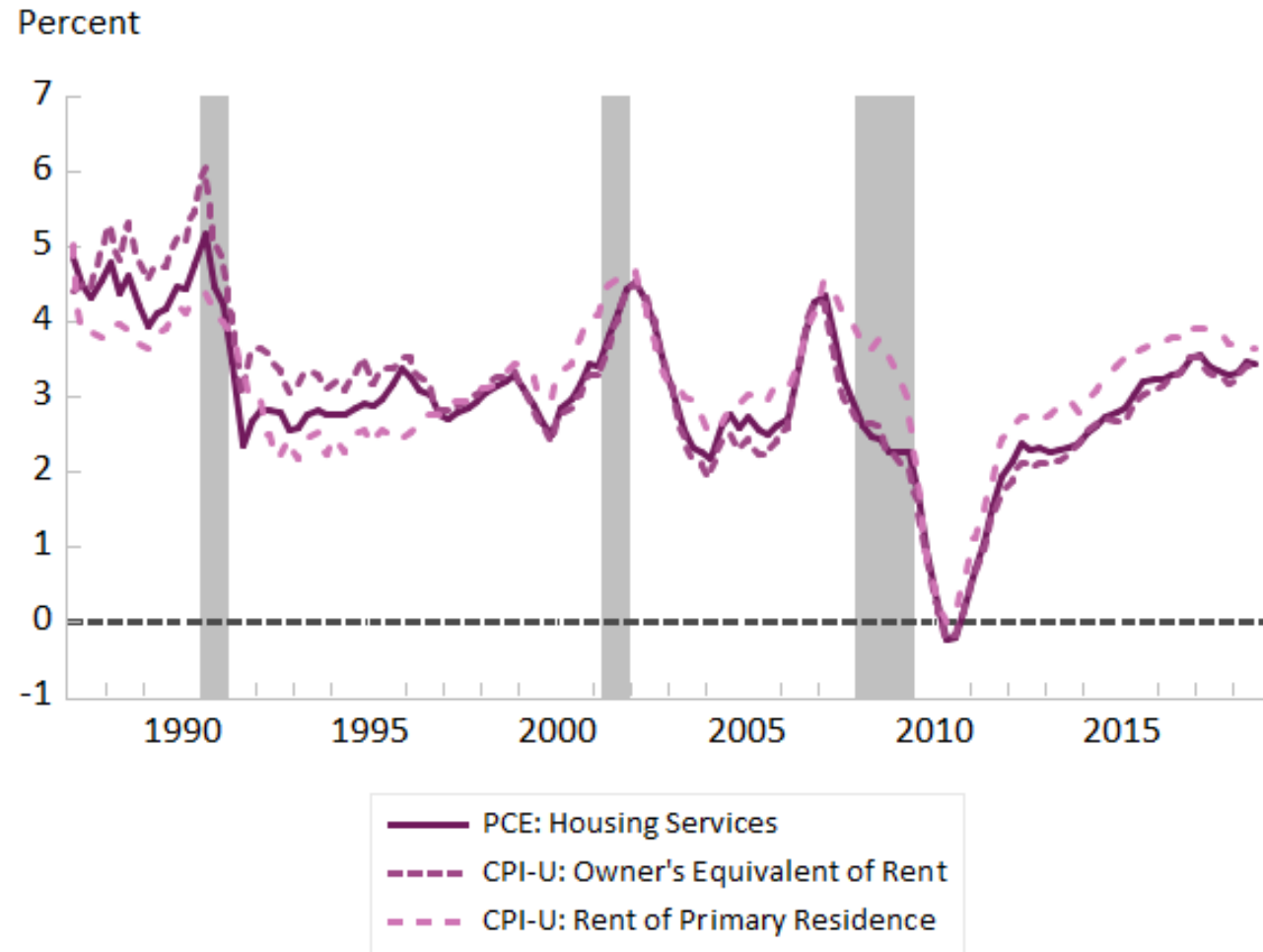
# **Cyclical Sensitivity of Inflation: Goods Versus Services**

# Phillips Curve Model at the Component Level

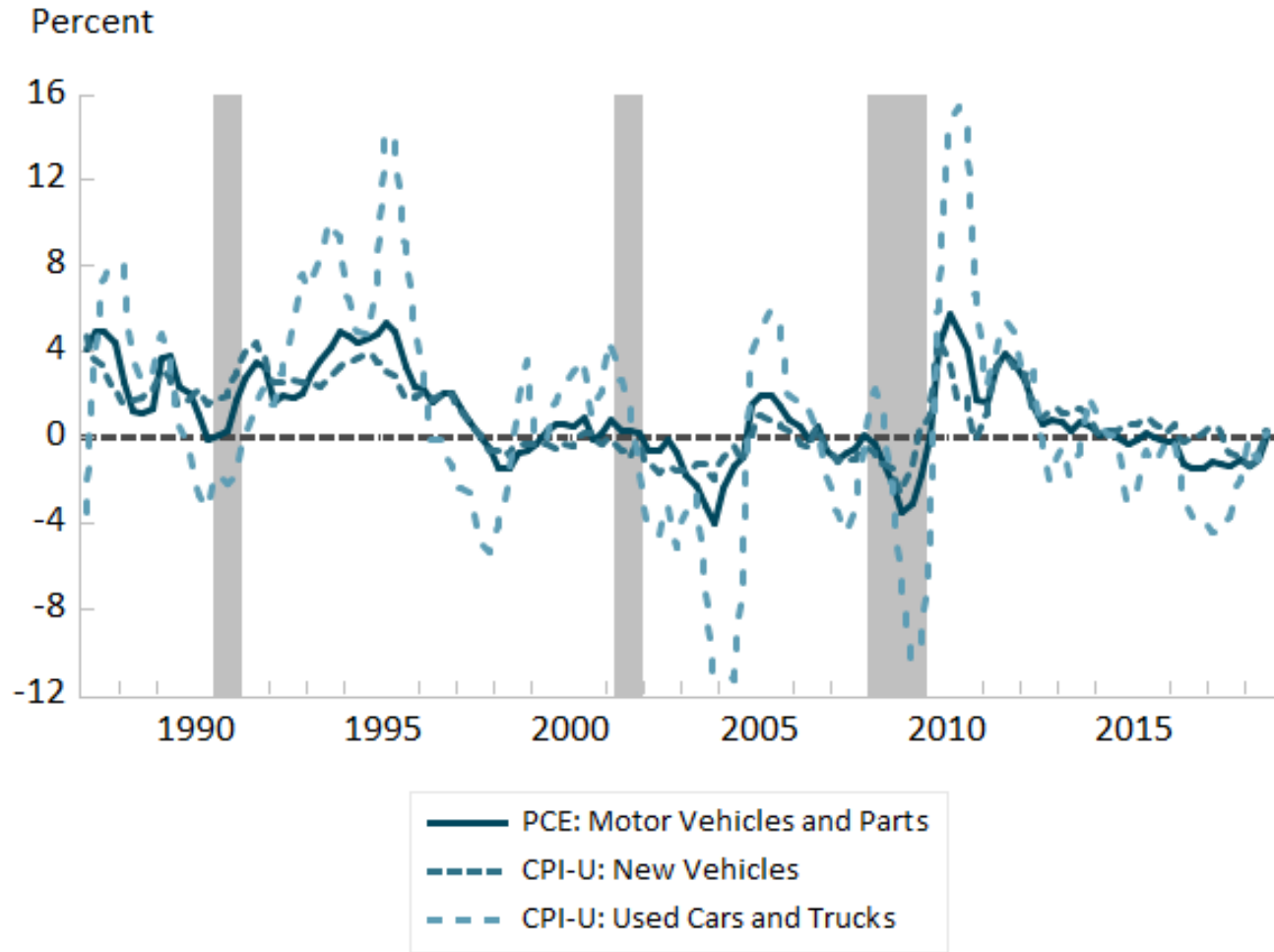
- **Goal:** Understanding why the *aggregate* Phillips curve is so flat
  
- **Method:** Estimating Phillips curve equations *at the component level*
  - Measure of slack: The unemployment gap (*CBO's estimate*)
  - Sample: 1998Q1–2018Q3 (stable inflation expectations)
  - Control for: Relative price of imports and energy goods, outliers (for example, “cash for clunkers”)
  - Similar to: Stock and Watson (2018); Struyven (2017)
  
- **Main Finding:** *Divergence between goods and services in terms of cyclical sensitivity*
  - Services: Remained largely pro-cyclical—for example, shelter
  - Goods: Not pro-cyclical in the past two decades
    - Dampening the slope of the aggregate Phillips curve
    - Exception: Food prices



# Shelter Inflation



# Auto Inflation



# Services: Largely Pro-Cyclical

	Unemployment Gap	Lagged Inflation	Constant	Adjusted R <sup>2</sup>
<b>PCE: Services Less Energy</b>	<b>-0.14</b> (0.00)	<b>0.32</b> (0.01)	<b>1.91</b> (0.35)	<b>0.46</b>
<b>PCE: Housing Services</b>	<b>-0.23</b> (0.00)	<b>0.58</b> (0.00)	<b>1.29</b> (0.24)	<b>0.80</b>
CPI-U: Owner's Equivalent of Rent	<b>-0.21</b> (0.00)	<b>0.62</b> (0.00)	<b>1.13</b> (0.24)	<b>0.78</b>
CPI-U: Rent of Primary Residence	<b>-0.15</b> (0.00)	<b>0.67</b> (0.00)	<b>1.16</b> (0.26)	<b>0.84</b>
<b>PCE: Health Care Services</b>	<b>-0.06</b> (0.38)	<b>0.62</b> (0.00)	<b>0.92</b> (0.26)	<b>0.42</b>
<b>PCE: Services Less Energy, Rent of Shelter &amp; Health care</b>	<b>-0.04</b> (0.50)	<b>0.35</b> (0.00)	<b>1.72</b> (0.28)	<b>0.38</b>
<b>CPI-U: Services Less Energy Services &amp; Rent of Shelter</b>	<b>-0.15</b> (0.01)	<b>0.40</b> (0.00)	<b>1.88</b> (0.40)	<b>0.34</b>
CPI-U: Medical Care Services	<b>-0.05</b> (0.51)	<b>0.70</b> (0.00)	<b>1.15</b> (0.45)	<b>0.34</b>
CPI-U: Food away from Home	<b>-0.09</b> (0.05)	<b>0.62</b> (0.00)	<b>1.05</b> (0.25)	<b>0.57</b>
CPI-U: Education Services	<b>-0.07</b> (0.16)	<b>0.93</b> (0.00)	<b>0.30</b> (0.29)	<b>0.81</b>
CPI-U: Transportation Services	<b>-0.02</b> (0.87)	<b>-0.11</b> (0.27)	<b>3.20</b> (0.36)	<b>0.16</b>

# Goods: Largely Not Pro-Cyclical, Except Food

	Unemployment Gap	Lagged Inflation	Constant	Adjusted R <sup>2</sup>
<b>PCE: Durable Goods</b>	<b>0.08</b> (0.31)	<b>0.28</b> (0.01)	<b>-1.54</b> (0.24)	<b>0.27</b>
<b>PCE: Motor Vehicles and Parts</b>	<b>0.31</b> (0.05)	<b>0.30</b> (0.00)	<b>-0.21</b> (0.25)	<b>0.43</b>
<b>PCE: Video, Audio, Photo &amp; Information Processing Equipment &amp; Media</b>	<b>0.16</b> (0.34)	<b>0.60</b> (0.00)	<b>-3.95</b> (0.87)	<b>0.44</b>
<b>PCE: Other Durable Goods (including Medical Equipments)</b>	<b>-0.10</b> (0.28)	<b>0.38</b> (0.00)	<b>-0.50</b> (0.19)	<b>0.27</b>
<b>PCE: Nondurable Goods Less Energy</b>	<b>-0.14</b> (0.05)	<b>0.73</b> (0.00)	<b>0.39</b> (0.17)	<b>0.44</b>
<b>PCE: Food &amp; Beverage Purchased for Off-Premises Consumpt</b>	<b>-0.24</b> (0.04)	<b>0.66</b> (0.00)	<b>0.71</b> (0.24)	<b>0.55</b>
CPI-U: Food at Home	<b>-0.27</b> (0.05)	<b>0.63</b> (0.00)	<b>0.82</b> (0.28)	<b>0.52</b>
CPI-U: Alcoholic Beverages	<b>-0.17</b> (0.04)	<b>0.34</b> (0.00)	<b>1.47</b> (0.26)	<b>0.16</b>
<b>PCE: Pharmaceutical &amp; Other Medical Products</b>	<b>-0.02</b> (0.88)	<b>0.33</b> (0.00)	<b>2.02</b> (0.39)	<b>0.20</b>
<b>PCE: Other Nondurable Goods</b>	<b>0.08</b> (0.46)	<b>0.25</b> (0.01)	<b>0.00</b> (0.18)	<b>0.42</b>
CPI-U: Apparel	<b>0.54</b> (0.00)	<b>0.14</b> (0.18)	<b>-0.69</b> (0.30)	<b>0.22</b>

# Goods Versus Services: Possible Explanations

## ▪ Services

- Prices are largely determined by domestic and/or local factors
  - Household maintenance, restaurants, etc.
- Cannot be inventoried

## ▪ Goods

- Lots of measurement issues and noise from one-off price shocks (Stock and Watson, 2018)
  - Measurement issue very severe for apparel, recreational goods, financial services, etc.
  - One-off price shocks: “cash for clunkers” (2009), federal tobacco tax hike (2009)
- Tend to be more heavily influenced by long-run structural forces
  - Globalization: Abdi et al. (2016) and others
  - “The Amazon effect”: Goolsbee and Klenow (2018)
  - Increasing industrial concentration?

# Forecasting Inflation at the Component Level

## ▪ Services Components

- Generally, Phillips curve equations at the component level work relatively well
- Special case: PCE health care services (policy plays a large role)
  - CBO's model incorporates CBO's projection of Medicare reimbursement rate growth

## ▪ Goods Components

- **“Top-down Approach”**: CBO currently uses core PCE inflation (from the aggregate Phillips curve) as an input in the equations for goods components
  - Keep track of movements in relative prices
  - Judgment in sector-specific trends
  - Control for relative price of imports, one-off price shocks, etc.

# **Modeling Inflation Expectations: Backward-Looking Versus Anchored**

# Estimating the Aggregate Phillips Curve

- **Reduced-form:**

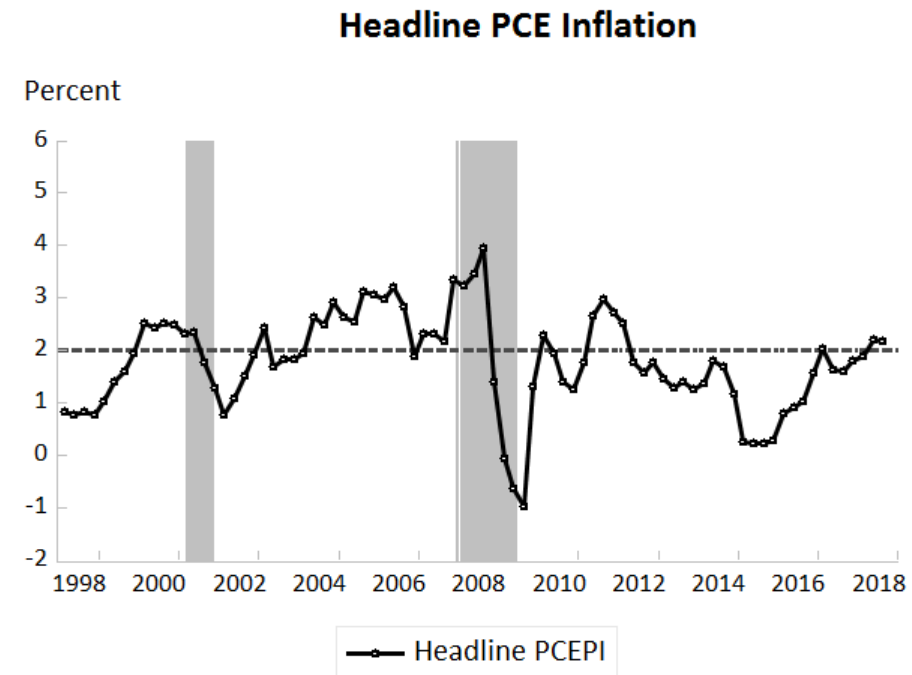
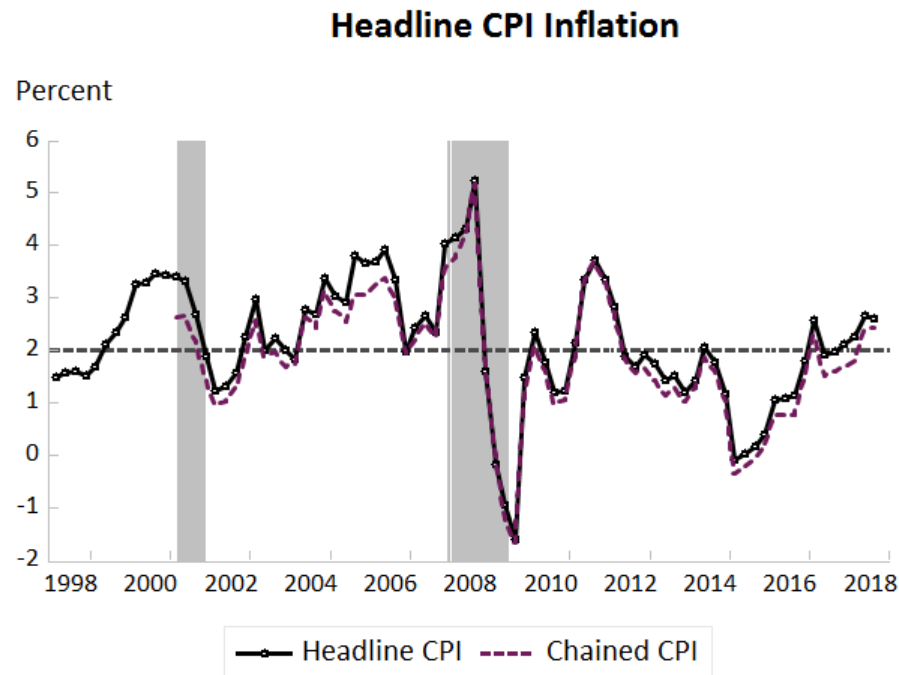
$$\pi_t = \alpha A(L)\pi_{t-1} + (1 - \alpha)\pi^* - \beta(U_t - U_t^*) + \gamma Z_t + \epsilon_t$$

- $A(L)\pi_{t-1}$ : Use four lags of past inflation
  - $\pi^*$ : Long-run inflation/“anchor”
  - $(U_t - U_t^*)$ : The unemployment gap (CBO’s estimate)
  - $Z_t$ : Supply-side shocks, including relative prices of imports and energy goods
  - Sample: 1998Q1–2018Q3
- Blanchard (2016): “The Phillips Curve: Back to the ’60s?”
    - Shows  $\alpha$  declined over time and is currently very small *for headline CPI*.
  - But component-level analysis implies that the measure of inflation matters
  - **This exercise: Try ten different measures of aggregate inflation**



# Ten Measures of Inflation

- Three measures of headline inflation
  - Headline CPI-U (BLS) and Headline PCEPI (BEA)
  - Chained CPI (BLS)

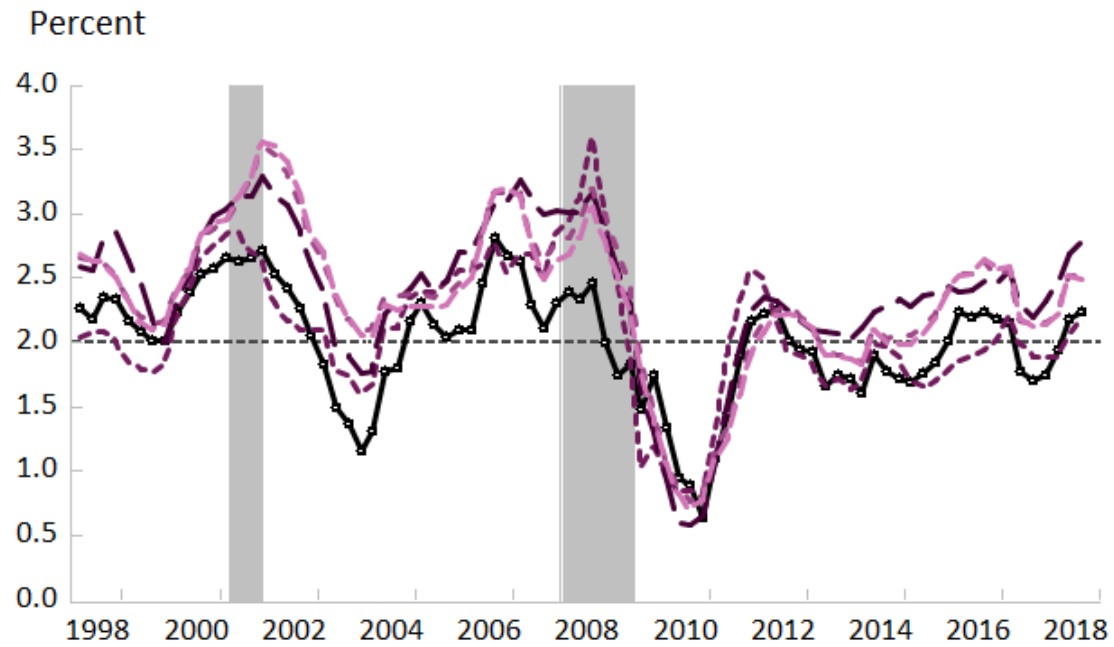


# Ten Measures of Inflation (Continued)

- **Seven measures of core inflation**
  - **Approach 1: Remove the most volatile price changes**
    - **XFE CPI-U** (BLS) and **XFE PCEPI** (BEA)
    - **Median CPI-U** and **16%-Trimmed-Mean CPI-U** (Federal Reserve Bank of Cleveland)
      - Rank price changes by size each month, and trim the items with price changes that are above or below a certain threshold
      - “Median” is just extreme trimming
    - **Trimmed-Mean PCEPI** (Federal Reserve Bank of Dallas)
      - Trimming point chosen optimally every month
  - **Approach 2: Remove the most frequent price changes**
    - **Sticky CPI-U** and **Sticky-XFE CPI** (Federal Reserve Bank of Atlanta)
      - Price changes every 4.3 months or longer (Bils and Klenow, 2004)

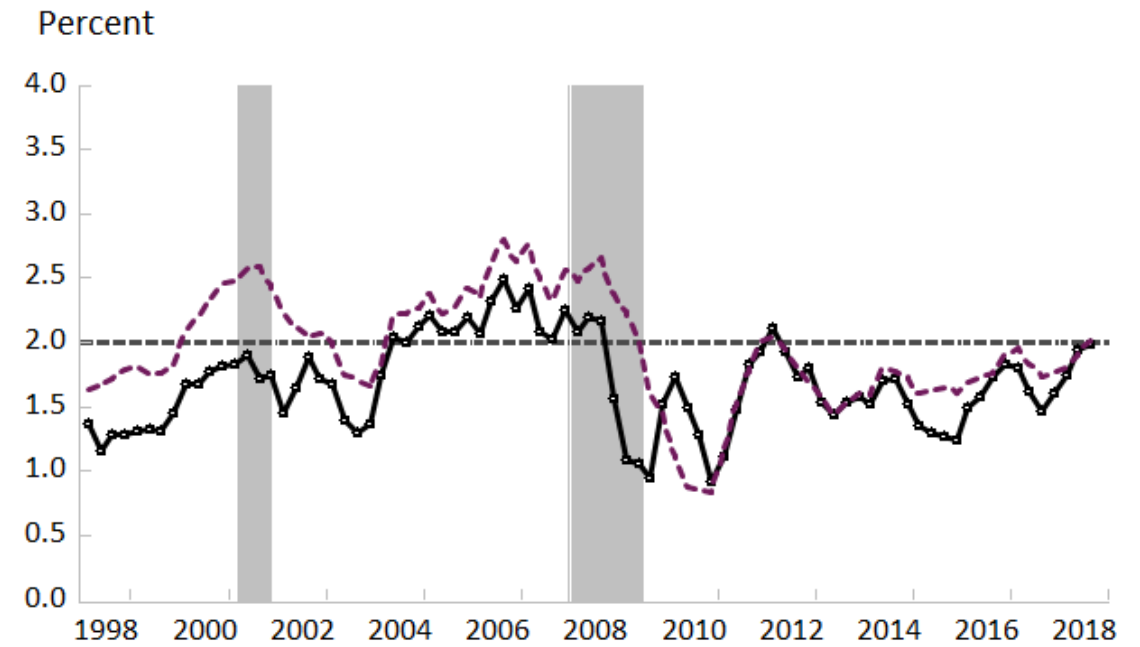
# Seven Measures of Core Inflation

## Core CPI Inflation



—○— Core-XFE CPI    - - - - 16%-Trimmed Mean CPI  
 — Median CPI    - - - - Sticky CPI  
 - - - - Sticky-XFE CPI

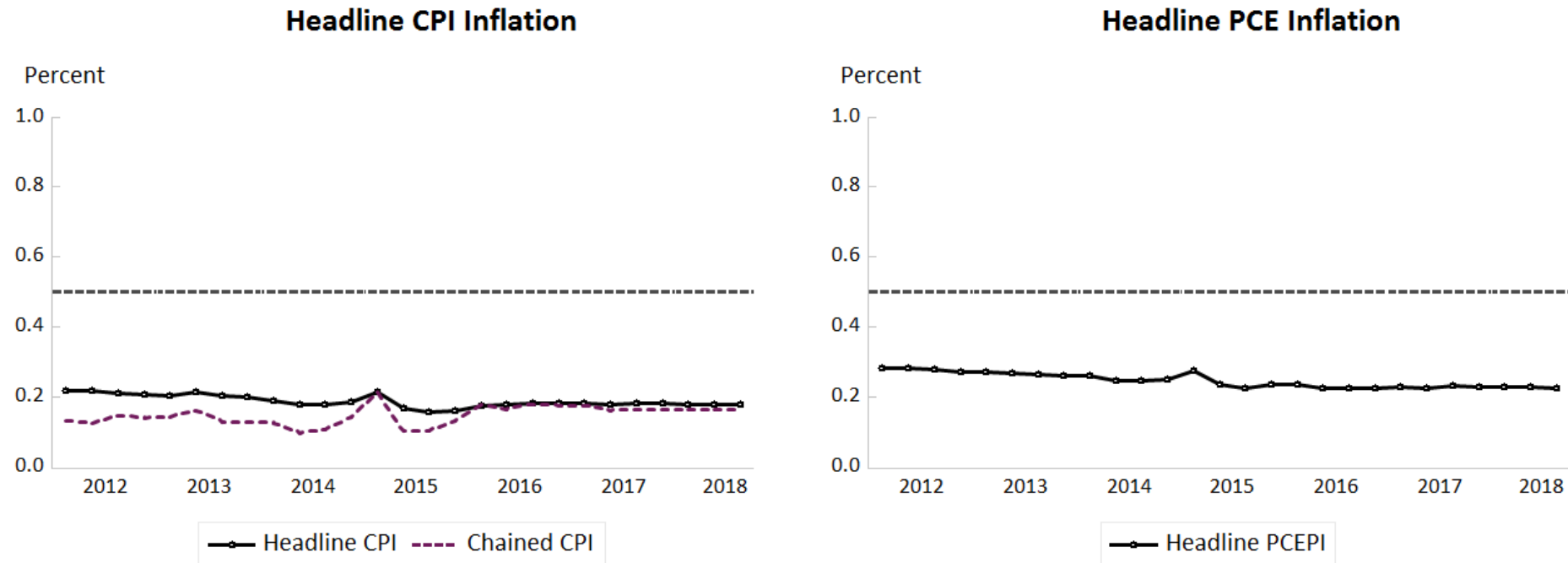
## Core PCE Inflation



—○— Core-XFE PCEPI  
 - - - - Trimmed Mean PCEPI

# Estimation Results: I

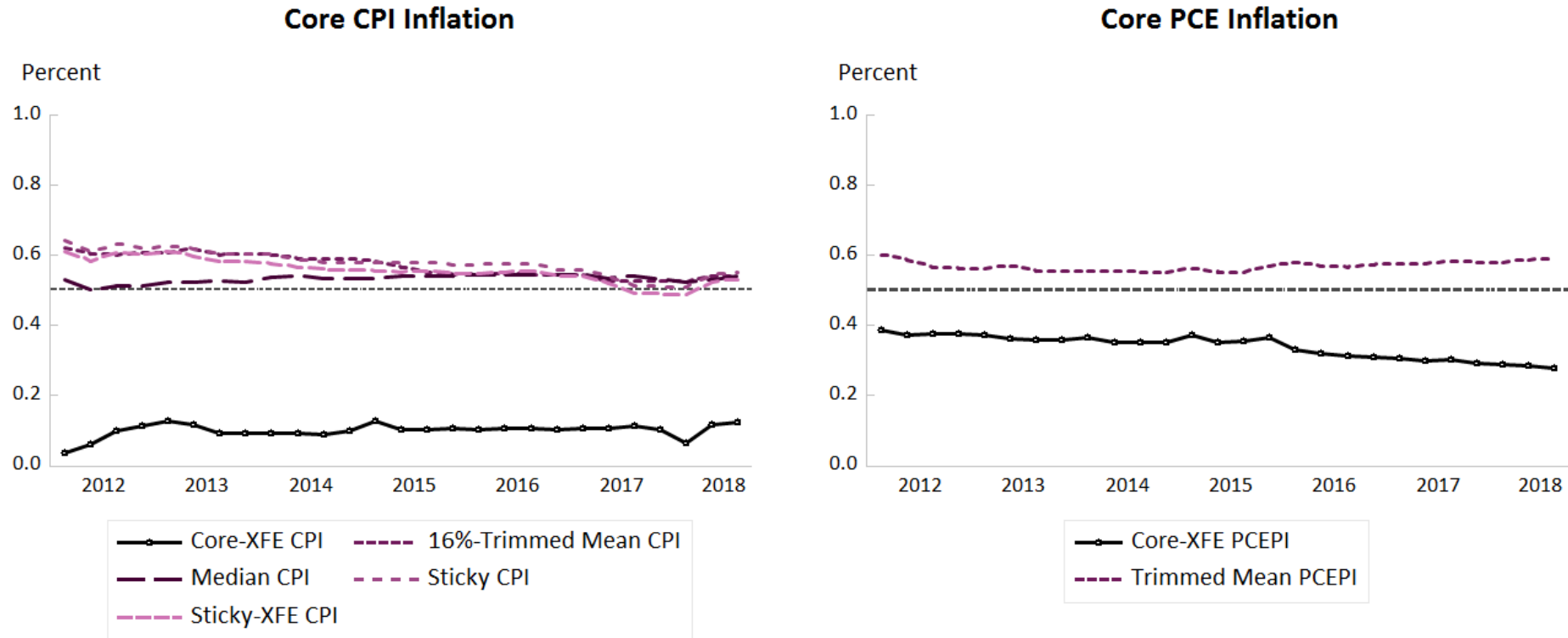
- **Relative weight of lagged inflation and constant/“anchor”:**
  - Overall inflation:  $\alpha \approx 0.2$ , consistent with Blanchard (2016) for headline CPI



This figure plots the sum of the estimated coefficients on lagged inflation terms using **recursive samples** that start in 1998Q1 and end in 2012Q1, 2012Q2, ..., and 2018Q1. The Phillips curve equations are “unrestricted,” as no assumption was imposed on the value of  $\pi^*$  before the estimation. Instead, the intercept of the equation, which, in theory, equals  $\alpha\pi^*$ , was estimated and then the values of  $\alpha$  and  $\pi^*$  were calculated by assuming the long-run restriction on the estimated coefficients.

# Estimation Results: I (Continued)

- **Relative weight of lagged inflation and constant/“anchor”:**
  - Overall inflation:  $\alpha \approx 0.2$ , consistent with Blanchard (2016) for headline CPI
  - Core inflation:  $\alpha \approx 0.5$ , particularly for non-XFE measures.



This figure plots the sum of the estimated coefficients on lagged inflation terms using **recursive samples** that start in 1998Q1 and end in 2012Q1, 2012Q2, ..., and 2018Q1. The Phillips curve equations are “unrestricted,” as no assumption was imposed on the value of  $\pi^*$  before the estimation. Instead, the intercept of the equation, which, in theory, equals  $\alpha\pi^*$ , was estimated and then the values of  $\alpha$  and  $\pi^*$  were calculated by assuming the long-run restriction on the estimated coefficients.

## Estimation Results: I (Continued)

Further analysis using **survey measures of inflation expectations** suggests:

- **Inflation expectations by consumers matter more** for inflation dynamics than the expectations by professional forecasters *for all ten measures of inflation*
  - Consumers' expectations more closely resemble those of firms (Coibion and Gorodnichenko, 2015)
  - Transmission of professional forecasters' views to consumers is weak in a low-inflation environment
  - Coibion et al. (2017): Similar finding for headline CPI
  
- **Long-run inflation expectations by consumers are “shock-anchored” but not “level-anchored”** (Ball and Mazumder, 2011)
  - Shock-anchoring: Transitory shocks not passed to expectations
  - Level-anchoring: Expectations tied to a particular level

# Estimation Results: II

- **Comparing measures of core inflation**
  - The Phillips curve fits the non-XFE measures very well
    - Average adj.  $R^2$  of non-XFE measures = 0.7
    - Ball and Mazumder (2014): Showed this for median CPI
  - XFEs are “outliers”, particularly XFE CPI-U (low  $\alpha$  and low  $R^2$ )
    - Average adj.  $R^2$  of XFE measures = 0.25
  
- **Possible explanation**
  - Fewer goods prices in the non-XFE core measures
    - Goods price changes are more volatile
    - Goods price changes occur more frequently

# CPI Components: Summary Statistics and Categorization

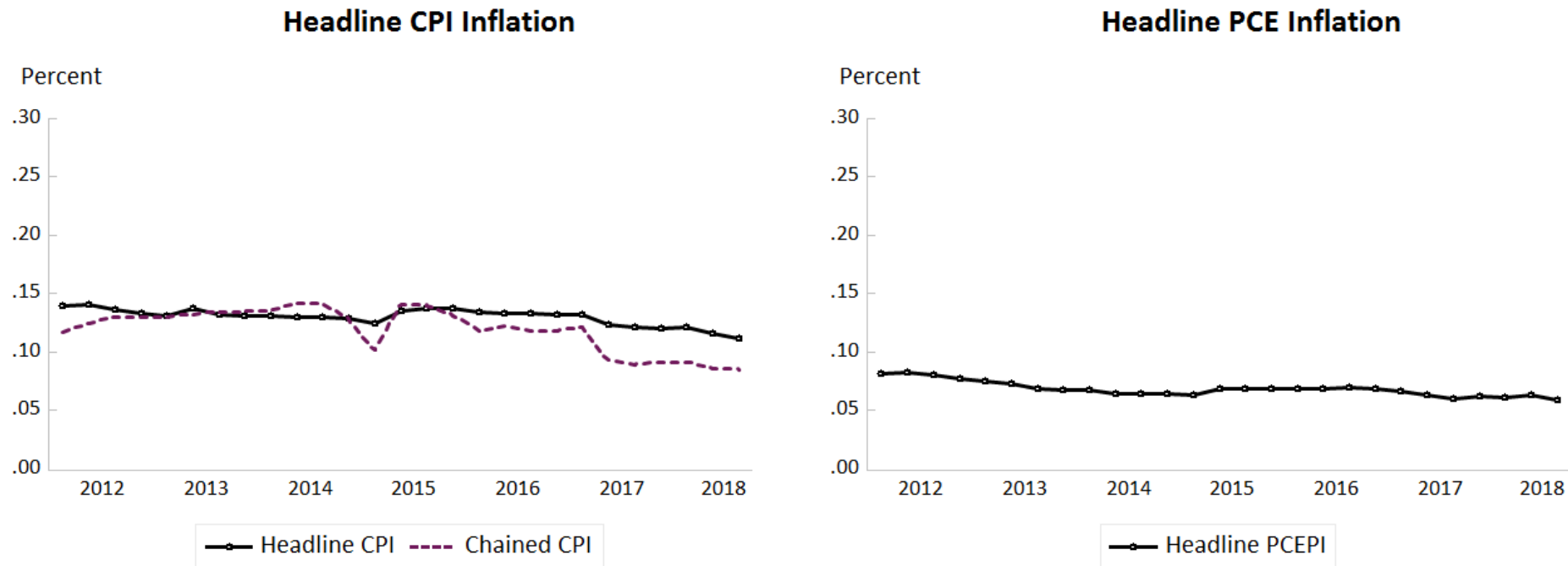
Major CPI Components	Summary Statistics				Categorization		
	Mean	Standard Deviation	Relative Importance (2017)	Change in Relative Importance: 2007-2017	XFE	Sticky CPI	Probability (= Median CPI) (1998-2007)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<b>Core (XFE) Services</b>							
Owner's Equivalent of Rent (OER)	2.7	1.1	23.2%	2.98%	Y	Y	52%
Rent of Primary Residence	3.2	1.1	7.9%	1.01%	Y	Y	5%
Medical Care Services	3.8	1.3	6.7%	2.33%	Y	Y	2%
Education Services	4.9	1.5	3.0%	0.58%	Y	Y	0%
Transportation Services	2.7	1.8	6.0%	-1.05%	Y	Y	5%
<b>Core (XFE) Goods</b>							
Apparel	-0.3	2.5	3.1%	-1.89%	Y	N	2%
New Vehicles	0.1	2.3	3.6%	-1.42%	Y	N	3%
Used Cars and Trucks	-0.3	8	2.1%	0.20%	Y	N	0%
Medical Care Goods	2.9	1.6	1.8%	0.59%	Y	Y	1%
<b>Food and Energy</b>							
Food away from Home	2.8	0.9	5.9%	0.19%	N	Y	11%
Food at Home	2.1	2.7	7.7%	-2.01%	N	N	6%
Energy	3.6	20.2	7.5%	0.78%	N	N	1%

The categorization of components into sticky CPI is based on Bryan and Meyer (2010), "Are Some Prices in the CPI More Forward Looking Than Others? We Think So," *Economic Commentary*, Federal Reserve Bank of Cleveland, <https://www.frbatlanta.org/-/media/documents/research/inflationproject/stickyprice/sticky-price-cpi-supplemental-reading.pdf>. The probabilities of a component's being the median CPI are based on the "revised methodology" that split the OER into four regional components. For more detail, see <https://www.clevelandfed.org/en/our-research/indicators-and-data/median-cpi/revised-methodology.aspx>.



# Estimation Results: III

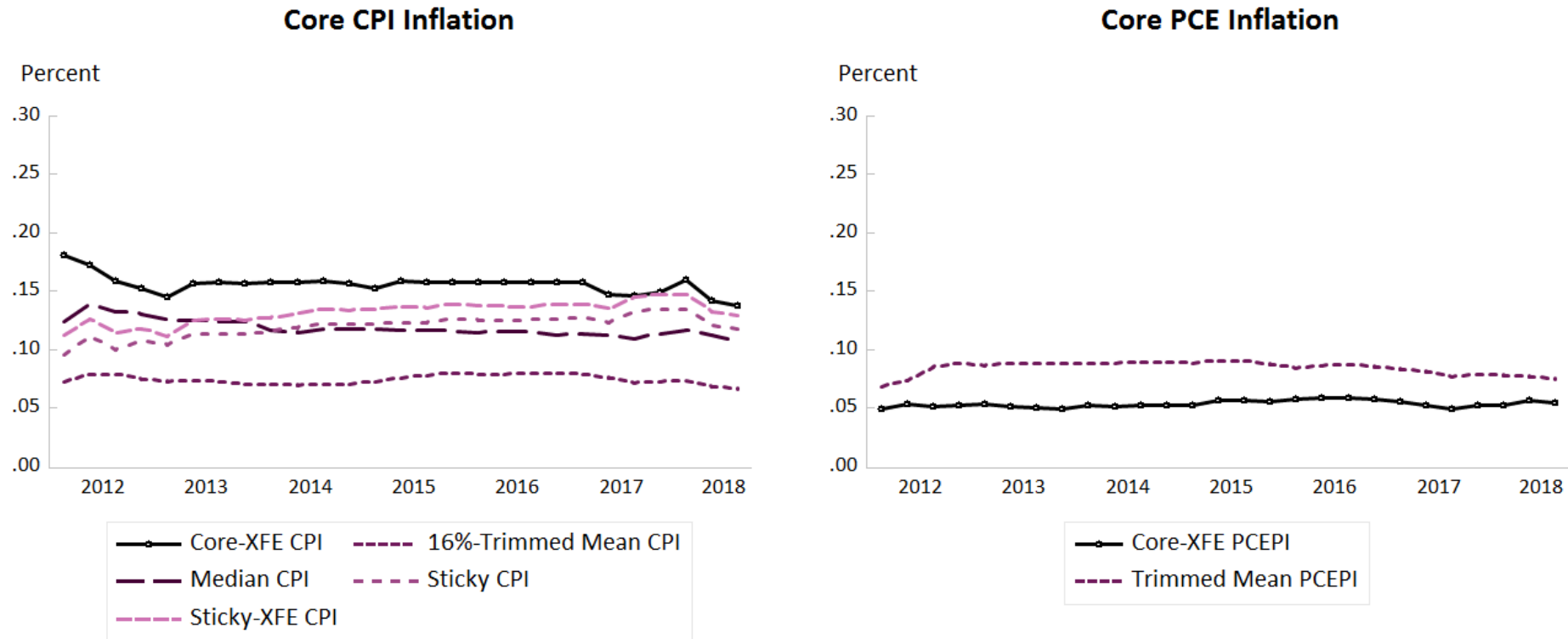
- **The slope of the Phillips curve: Flat, but steeper for CPIs than PCEPIs**
  - $\beta = 0.05 \sim 0.1$  for PCEPIs, but  $= 0.1 \sim 0.2$  for CPIs
  - Why: Shelter, the most cyclically sensitive component, has a much larger weight in CPI than in PCEPI



This figure plots the sum of the estimated coefficients on lagged inflation terms using **recursive samples** that start in 1998Q1 and end in 2012Q1, 2012Q2, ..., and 2018Q1. The Phillips curve equations are “unrestricted,” as no assumption was imposed on the value of  $\pi^*$  before the estimation. Instead, the intercept of the equation, which, in theory, equals  $\alpha\pi^*$ , was estimated and then the values of  $\alpha$  and  $\pi^*$  were calculated by assuming the long-run restriction on the estimated coefficients.

## Estimation Results: III (Continued)

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# **Reviewing the Findings**

# Conclusions

- **Phillips-curve analysis at the component level** provides insight into:
  - **Cyclical sensitivity of aggregate inflation**
    - For most service components and food: inflation process is pro-cyclical
    - For most non-food good components, inflation process is not pro-cyclical
      - Need better understanding and models for goods price inflation
  - **Difference in the behaviors of various inflation measures**
    - CPI is more cyclically sensitive than PCEPI because shelter has larger share in CPI
    - Non-XFE measures of core inflation better capture movements in trend inflation because they contain fewer noisy goods components
  
- **The aggregate Phillips curve has shifted away from “accelerationist” toward an “anchored” form, but the process appears incomplete**
  - Need better understanding of the formation process of inflation expectations, particularly those of consumers and firms

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