Components of Inflation, Inflation Forecasting, and the Phillips Relation

June 4, 2016

James Stock, Harvard Economics
Mark Watson, Princeton University
1. Introduction

\[ \pi_t - \pi_{t-4} \text{ vs. } \text{ugap}_t \]

4-qtr change in 4-qtr inflation (PCEExE) v. unemployment gap
1960-83 (dots) 1984-99 (diamond) 2000-2016 (triangle)
1. Introduction

$$\pi_t - \pi_{t-4} \text{ vs. } u_{gap_t}$$

4-qtr change in 4-qtr inflation (PCExE) v. unemployment gap
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4-qtr change in 4-qtr inflation (PCEExE) v. unemployment gap
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1. Introduction

\[ \pi_t - \pi_{t-4} \text{ vs. Short-term unemployment rate}_t \]

4-qtr change in 4-qtr inflation (PCE\text{ExE}) v. short-term un. rate

1960-83 (dots) 1984-99 (diamond) 2000-2016 (triangle)
Where is the cyclical pressure on inflation?

<table>
<thead>
<tr>
<th>Quarter</th>
<th>PCE</th>
<th>Core PCE</th>
<th>CPI</th>
<th>Core CPI</th>
<th>17-component trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015q2</td>
<td>2.2</td>
<td>1.9</td>
<td>2.4</td>
<td>2.3</td>
<td>1.4</td>
</tr>
<tr>
<td>2015q3</td>
<td>1.3</td>
<td>1.4</td>
<td>1.4</td>
<td>1.8</td>
<td>1.3</td>
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<tr>
<td>2015q4</td>
<td>0.3</td>
<td>1.3</td>
<td>0.8</td>
<td>2.2</td>
<td>1.2</td>
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<td>2016q1</td>
<td>0.3</td>
<td>2.1</td>
<td>-0.3</td>
<td>2.7</td>
<td>1.5</td>
</tr>
</tbody>
</table>
1. Introduction

**This paper: Cyclically Sensitive Inflation**

- This paper introduces “cyclically sensitive inflation” and provides a preliminary estimate

- Treat the Phillips curve as a statistical measurement problem
  - Some components of inflation are poorly measured
  - We would expect other components to exhibit extreme price sluggishness
  - Other components of inflation would be expected to have a very low signal-to-noise ratio – so their demand/Phillips response would be difficult to decipher

- Combine measurement facts (BLS methods) and time series techniques
1. Cyclically sensitive inflation: motivation

2. Literature

3. Components: review of BLS methods

4. Components: cyclical properties

5. Measuring trend inflation using components

6. Cyclically sensitive inflation
   a) methods
   b) time variation

7. Next steps
Selected literature


- **Inflation forecasting**: Atkeson-Ohanian (2000), many others

- **Closest**: this work extends Stock and Watson (“Core Inflation and Trend Inflation” forthcoming) which uses the 17 components to estimate trend inflation. Here, the goal is estimation of cyclically sensitive inflation, not trend inflation
3. Components:
Data and Review of BLS and BEA Methods
Price index measurement: introductory comments

- It is well known that there are major challenges with price index construction
  - Discussed below

- These defects matter for applications in which a correct reading of the rate of inflation matters.
  - Policies and projections that involve some real and some nominal components, e.g. indexing policies, Social Security funding projections, etc.
  - Generally not for purely nominal projections (e.g., debt-GDP ratio)
  - Monetary policy: not obvious.
    - Is deflation the problem (unobserved), or ZLB (observed)?
  - This paper: not concerned with the rate of inflation, but changes in the rate of inflation.
    - Bias doesn’t matter as long as the bias is unrelated to real economic activity
    - Measurement noise is just a statistical nuisance
    - Measurement bias that is related to real economic activity because of index construction bias is a problem, want to eliminate
The PCE price index: a brief review of methods

- The PCE price index is computed by the Bureau of Economic Analysis (BEA)
  - Most component price series are CPI indexes for components, computed by the Bureau of Labor Statistics (BLS)
  - Differences between PCE-PI and CPI:
    - PCE concept is final consumption, CPI is “out of pocket” spending
    - Share weights are from the NIPA surveys
    - PCE-PI is revised for methodological changes (if possible), CPI is not
    - Some divergence in price concepts, in which PCE uses PPI not CPI prices

- The market price component of the CPI has 211 item strata
  - Single panel sample monthly: food at home, lodging, most consumer end-energy goods, telephone services, used cars, some odds and ends
  - 2 panels, each sampled every other month: everything else except rent, at least in some regions
  - 6 panels, each sampled every 6 months: rent
  - The market price component of the CPI has 211 item strata
  - Market-based CPI has several well-known problems
    - New goods problem: no quality adjustment, just skip first month price
    - Replacement goods problem: quality adjustment by production cost or hedonic regression
The PCE price index: a brief review of methods, ctd.

- The CPI is also computed for sectors without posted market prices. There are various methodologies:
  - The first step is defining the unit to be priced. For example
  - For legal services: an hour of a law office’s time
  - For hospital services: a service bundle (e.g., 2 day stay + 1 cardiac catheterization + 2 EKGs + 2 IV doses blood thinner drug + ...)
  - These are priced from (randomly selected) bills or interviews
  - Other price indexes for unpriced services include unpriced services of nonprofits (religious institutions, etc.), unpriced banking services (liquidity services)

- Special indexes:
  - PCE-xE: excludes gasoline & other energy goods + energy utilities component of housing
  - PCE-xFE: also excludes food at home (but not food at restaurants)
  - Market-based CPI (excludes all non-market price estimates)
## PCE components and their shares, sorted by 2000-2014 share

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing and utilities</td>
<td>0.18</td>
<td>0.17</td>
<td>0.18</td>
<td>0.18</td>
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<tr>
<td>Health care</td>
<td>0.11</td>
<td>0.07</td>
<td>0.13</td>
<td>0.16</td>
</tr>
<tr>
<td>Other services</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.09</td>
</tr>
<tr>
<td>Other nondurable goods</td>
<td>0.08</td>
<td>0.08</td>
<td>0.07</td>
<td>0.08</td>
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<tr>
<td>Food and beverages for off-premises consumption</td>
<td>0.12</td>
<td>0.16</td>
<td>0.10</td>
<td>0.08</td>
</tr>
<tr>
<td>Financial services and insurance</td>
<td>0.06</td>
<td>0.05</td>
<td>0.07</td>
<td>0.08</td>
</tr>
<tr>
<td>Food services and accommodations</td>
<td>0.06</td>
<td>0.06</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>Motor vehicles and parts</td>
<td>0.05</td>
<td>0.06</td>
<td>0.05</td>
<td>0.04</td>
</tr>
<tr>
<td>Recreation services</td>
<td>0.03</td>
<td>0.02</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>Clothing and footwear</td>
<td>0.05</td>
<td>0.07</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td>Recreational goods and vehicles</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Gasoline and other energy goods</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.03</td>
</tr>
<tr>
<td>Transportation services</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Furnishings and durable household equipment</td>
<td>0.04</td>
<td>0.04</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Final consumption expenditures of nonprofit institutions serving households (NPISHs)</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>Other durable goods</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>
PCE (green) and component (orange): Housing ex energy util. (qtrly)

Rent paid by renters
Actual market rent excluding utilities
6 rotating panels, surveyed every 6 months
Price index(t) = This month’s panel price relative × price index(t-1)

Owner-equivalent rent
Post-1983: Actual market rent excluding utilities
Pre-1983: Payment flows (mortgage payments, etc)
6 rotating panels, index construction as for renters

Misc.
Surveyed units fractionally represent rental and owned units
Boarding schools, group homes use renter’s rent index
Utilities: CPI for water & sewer maint; CPI for garbage & trash collection
Housing: energy utilities

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electricity</strong></td>
<td>CPI for electricity</td>
</tr>
<tr>
<td><strong>Natural gas</strong></td>
<td>CPI for utility-provided natural gas</td>
</tr>
</tbody>
</table>
Health care (expenditure share 2000-2016 = 0.16): CPI

CPI v. PCE
CPI covers out-of-pocket medical (paid by consumers). PCE covers consumption of medical services. Most medical services in the U.S. do not have a market price – they are negotiated health plan prices.

CPI: Outpatient physician’s services, paramedics, hospitals, nursing homes
Provision-of-services concept. CPI outpatient: price of visit for a specific illness. CPI hospital (post-87): price of bundle of services provided (3-day stay + 1 catheterization + 2 EKGs +... ) by insurer reimbursement category. CPI pharma: by drug. Pre-87: cost of hospital inputs.

Dental & other medical
CPI for dental services, CPI for other medical services.
## Health care (0.16): PCE

<table>
<thead>
<tr>
<th>PPI concept</th>
<th>PPI usually first transaction price rec’d by producer. For health care, PPI since 1993 is DRG-based, broken out by service providers</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCE: Physician services</td>
<td>PPI for physician offices. Unit is office visit for a given condition</td>
</tr>
<tr>
<td>PCE: hospital services</td>
<td>PPI for hospitals. Unit is a hospital episode for a given condition</td>
</tr>
<tr>
<td>PCE: nursing homes</td>
<td>PPI for nursing homes. Cost of inputs basis (hourly wages etc.)</td>
</tr>
<tr>
<td>PCE: paramedical</td>
<td>PPI for paramedical</td>
</tr>
<tr>
<td>Dental &amp; other medical</td>
<td>Uses CPIs for dental services, for other medical services</td>
</tr>
<tr>
<td>Service</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Communication</td>
<td>CPI for wireless phone service, CPI for land line phone service</td>
</tr>
<tr>
<td>Internet</td>
<td>CPI for internet services</td>
</tr>
<tr>
<td>Education</td>
<td>CPI for college education; CPI for private primary &amp; secondary schools</td>
</tr>
<tr>
<td>Legal, accounting</td>
<td>Cost basis (cost of 1 hr lawyer’s time)</td>
</tr>
<tr>
<td>Social services</td>
<td>Cost basis, some CPI (child care)</td>
</tr>
<tr>
<td>Misc.</td>
<td>CPI for postage, CPI for funeral services, CPI for haircuts; net foreign</td>
</tr>
<tr>
<td></td>
<td>travel (complicated)</td>
</tr>
</tbody>
</table>
Other nondurable goods (0.08)

- Tobacco: CPI-tobacco
- Pharmaceuticals: CPIs for prescription & OTC drugs, CPI for med. eqpt sold to consumers
- Recreational nondurables: CPIs for toys, plants & flowers, pets, photographic supplies, ...
- Personal care: Various CPIs for personal care items
- Misc. home goods: CPIs: newspapers & magazines, household supplies
- Spending abroad: (net, including in-kind personal remittances) complicated, non-mkt
Food & beverages off-premises (0.08)

<table>
<thead>
<tr>
<th>Food &amp; nonalcoholic beverages, off-premises</th>
<th>Detailed price components for food at home</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol, off-premises</td>
<td>Various CPIs (beer, wine, distilled spirits) for off-premises</td>
</tr>
</tbody>
</table>
Financial services & insurance (0.08)

**Financial services provided w/out payment**
Estimated based on imputed below-market interest on checking account. Alternative interest rate changed to “stabilized” (smoothed) rate in 2013, revised back to 1985

**Financial fees**
CPI for checking account and other bank services (market prices).

**Insurance**
Price index is for the value of insurance services provided (risk pooling, intermediation) = all premiums – expected losses; cost-based using PPI

**Brokers’ fees**
PPI (cost-based)
### Food services & accommodations (0.06)

<table>
<thead>
<tr>
<th>Purchased meals &amp; beverages</th>
<th>CPI for categories of purchased meals &amp; beverages (restaurant meals, bars, fast food, etc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutional food &amp; drink</td>
<td>Use market-based CPI for purchased meals &amp; beverages by category</td>
</tr>
<tr>
<td>Accommodations</td>
<td>CPI for purchased lodging away from home. Boarding at schools: separate (market-price) CPI</td>
</tr>
</tbody>
</table>

![Chart showing percentage change over time for food services & accommodations](chart.png)
Motor vehicles & parts (0.04)

New cars & trucks: CPI-new cars: sticker price + 30-day average dealer markup or discount. Year to year quality changes priced on production cost.

Used cars & trucks: Secondary source price data, with quality adjustments when new

Parts: CPI for tires; CPI for parts
### Recreation services (0.04)

<table>
<thead>
<tr>
<th>Category</th>
<th>CPI Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sports centers &amp; clubs, theaters, museums, etc.</td>
<td>CPI for specific categories, e.g. club dues and fees; admission to sporting events. Monthly/bi-monthly/6-month sample</td>
</tr>
<tr>
<td>Audio/video &amp; info processing services</td>
<td>CPI for cable &amp; satellite TV; CPI for film processing; CPI for video/audio rental</td>
</tr>
<tr>
<td>Other</td>
<td>Gambling: CPI-U; pet care: CPI-veterinary services, etc.</td>
</tr>
</tbody>
</table>
Clothing & footwear (0.03)

Market purchased clothing
Various CPIs. Note new/replacement goods issue however.

Military & uniforms
Cost-based
Recreational goods & vehicles (0.03)

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video, audio, home computers</td>
<td>Various CPIs including CPI for home computers, CPI for computer software and accessories, and CPI for consumer digital communications and information processing eqpt</td>
</tr>
<tr>
<td>Sporting eqp</td>
<td>CPI for sporting eqpt</td>
</tr>
<tr>
<td>Recreational books</td>
<td>CPI for recreational books</td>
</tr>
<tr>
<td>Musical instruments</td>
<td>CPI for musical instruments</td>
</tr>
</tbody>
</table>
Gasoline & other energy goods (0.03)

<table>
<thead>
<tr>
<th>Motor fuels</th>
<th>CPI for motor fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other fuels</td>
<td>CPIs for propane, kerosene, wood</td>
</tr>
</tbody>
</table>

% at annual rate

1960q1 1980q1 2000q1 2020q1
Transportation services (0.03)

<table>
<thead>
<tr>
<th>Service</th>
<th>Index Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airline travel</td>
<td>PPI (cost-based)</td>
</tr>
<tr>
<td>Intracity</td>
<td>CPI (covers taxis, busses, etc)</td>
</tr>
<tr>
<td>Intercity busses, trains</td>
<td>CPI (market prices)</td>
</tr>
<tr>
<td>Water</td>
<td>CPI (ferries, etc.)</td>
</tr>
</tbody>
</table>
Furnishings & household durables (0.03)

<table>
<thead>
<tr>
<th>Category</th>
<th>CPI Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furniture &amp; bedding</td>
<td>CPI for furniture &amp; bedding; CPI for clocks &amp; lamps; related CPIs</td>
</tr>
<tr>
<td>Household appliances</td>
<td>Various CPIs</td>
</tr>
<tr>
<td>Tools, house &amp; garden eqpt</td>
<td>Various CPIs</td>
</tr>
</tbody>
</table>
Final consumption expenditures of nonprofit institutions serving households (NPISHs) (0.03)

NPISH definition: Current operating expenditures by nonprofits less sales to households and other sectors.

Prices: By construction, essentially everything in NPISHs does not have a market price, so costs of inputs are used for priced outputs. Example: price of 1 hour of a minister’s time = minister’s hourly wage.
Misc. durable goods | Watches, jewelry, educational books, luggage, telephone equipment. All based on CPIs (market prices)
4. Estimating Trend Inflation using Components
Unobserved component/stochastic volatility model

Stock-Watson (2007) UC-SV model, extended for internally handled outliers

\[ \pi_t = \tau_t + \varepsilon_t \]  
\[ \tau_t = \tau_{t-1} + \sigma_{\Delta \tau, t} \eta_{\tau, t} \]  
\[ \varepsilon_t = \sigma_{\varepsilon, t} s_t \eta_{\tau, t} \]

trend + stationary component
random walk trend
stationary component serially uncorrelated

\[ \Delta \ln(\sigma_{\Delta \tau, t}^2) = \gamma_{\Delta \tau} \nu_{\Delta \tau, t} \]  
\[ \Delta \ln(\sigma_{\varepsilon, t}^2) = \gamma_{\varepsilon} \nu_{\varepsilon, t} \]

stochastic volatility in trend
stochastic volatility in stationary

\[ \left( \eta_{\varepsilon}, \eta_{\tau}, \nu_{\varepsilon}, \nu_{\Delta \tau} \right) \text{ i.i.d. } N(0, I_4) \]

normal errors, except for:

\[ s_t = \begin{cases} 1 \text{ with probability } p \\ U[2,10] \text{ with probability } 1-p \end{cases} \]

outlier adjustment (new)

• The model has a TV-IMA(1,1) representation (TV Nelson-Schwert (1977))
• 3 parameters: \( \gamma_{\varepsilon}, \gamma_{\Delta \tau}, p \), estimated by Bayes methods (diffuse prior over parameters)
Multivariate extension: smooth over time and components

Data: 17 top-level components of PCE (housing divided into energy and ex-E)

MUCSVO model:

\[
\begin{bmatrix}
\pi_{1t} \\
\pi_{2t} \\
\vdots \\
\pi_{nt}
\end{bmatrix}
= \begin{bmatrix}
\alpha_{1t} \\
\alpha_{2t} \\
\vdots \\
\alpha_{nt}
\end{bmatrix}
+ \begin{bmatrix}
\beta_{1t} \\
\beta_{2t} \\
\vdots \\
\beta_{nt}
\end{bmatrix}
\tau_c^t + \begin{bmatrix}
\varepsilon_{1t} \\
\varepsilon_{2t} \\
\vdots \\
\varepsilon_{nt}
\end{bmatrix}
+ \begin{bmatrix}
\tau_{1t} \\
\tau_{2t} \\
\vdots \\
\tau_{nt}
\end{bmatrix}
+ \begin{bmatrix}
t_{nt} \\
\vdots
\end{bmatrix}
\]

- trend \(i\) and common trend follow random walk with SV
- stationary \(i\) and common stationary are serially uncorrelated with SV
- trend and stationary components follow SV processes (like univariate)
- outliers indicators \(s_{it}\) are independent
- Aggregate (average) inflation and trend is computed using share weights \(w_{it}\)

\[
\tau_t = \sum_{i=1}^{16} w_{it} \left( \alpha_{i,t} \tau_{c,t} + \tau_{i,t} \right)
\]

- full Bayes estimation
- note that cointegration of components is possible but not imposed
MUCSVO estimates: Food & bev. off-premises

Notes: Panel (a) inflation is the sector shown in the figure heading and the full-sample posterior mean of the sectoral trend. The other panels plot the full-sample posterior median and (point-wise) 67% intervals for the sector-specific parameters.
Approximate weights: MUCSVO-17 and expenditure share

- MUCSVO weight
- Expenditure share
PCE-all and 17-component trend estimate (quarterly)
PCE-xE and 17-component trend estimate (quarterly)
5. Components: Cyclical Properties
4. Cyclical properties of components

**Cyclical Properties of Components**

**Phillips curves, component-wise**
- Do components have different cyclical properties?
- Do some components observe a Phillips relation?
- If so,
  - how do cyclical properties of components change over time?
  - does that relate to measurement quality?

**Figures**
Band-pass filtered component rates of inflation (quarterly) and GDP growth
- 6-32 quarter pass band
- “cyclical component of inflation and statistical estimate of GDP gap”
Band-pass filtered components and GDP (6-32 qtrs, standardized)
Band-pass filtered components and GDP (6-32 qtrs, standardized)
Band-pass filtered components and GDP (6-32 qtrs, standardized)
Band-pass filtered components and GDP (6-32 qtrs, standardized)
Band-pass filtered components and GDP (6-32 qtrs, standardized)
Band-pass filtered components and GDP (6-32 qtrs, standardized)
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Band-pass filtered components and GDP (6-32 qtrs, standardized)
Band-pass filtered components and GDP (6-32 qtrs, standardized)
Band-pass filtered components and GDP (6-32 qtrs, standardized)
Band-pass filtered PCE-xE and GDP (6-32 qtrs, standardized)
Band-pass filtered PCE-xE and GDP (6-32 qtrs, standardized)
Band-pass filtered PCE-xE and GDP (6-32 qtrs, standardized)
### Full-sample exploratory regressions: components Phillips curves

<table>
<thead>
<tr>
<th>Component</th>
<th>Unempl</th>
<th>Ugap-CBO</th>
<th>U&lt;27</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing ex gas &amp; electric util</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Gas &amp; electric util</td>
<td>0.683</td>
<td>0.547</td>
<td>0.205</td>
</tr>
<tr>
<td>Health care</td>
<td>0.006</td>
<td>0.196</td>
<td>0.121</td>
</tr>
<tr>
<td>Other services</td>
<td>0.013</td>
<td>0.033</td>
<td>0.000</td>
</tr>
<tr>
<td>Other nondurable goods</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Food &amp; beverages-off-premises</td>
<td>0.027</td>
<td>0.021</td>
<td>0.022</td>
</tr>
<tr>
<td>Financial services &amp; insurance</td>
<td>0.059</td>
<td>0.094</td>
<td>0.309</td>
</tr>
<tr>
<td>Food services &amp; accommodations</td>
<td>0.000</td>
<td>0.001</td>
<td>0.000</td>
</tr>
<tr>
<td>Motor vehicles and parts</td>
<td>0.078</td>
<td>0.149</td>
<td>0.135</td>
</tr>
<tr>
<td>Recreation services</td>
<td>0.002</td>
<td>0.002</td>
<td>0.000</td>
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<td>Clothing &amp; footwear</td>
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<td>Recreational goods &amp; vehicles</td>
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<td>Gasoline &amp; other energy goods</td>
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<td>Furnishings &amp; durable hh eqpt</td>
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- **Direct 4-qtr ahead forecasting regression**
- Dependent variable is cumulative 4-qtr inflation over next 4 quarters
- Predictors are 4 lags of $\Delta \pi$, $u$
- Estimation 1984q1-2016q1 (no out-of-sample)
- Entries are p-values on lags of the unemployment rate (HAC SEs)
6. Cyclically Sensitive Inflation
Cyclically sensitive inflation: methods

Questions
- What series enter “cyclically sensitive inflation”
- What weights do they get and how do those compare to share weights
- How much time variation in weights
- [What is cyclically sensitive inflation reading today?]

Preliminary data restriction
- Eliminate four categories based on *a-priori* concerns about measurement:
  - Recreational goods & vehicles
  - Clothing & footwear
  - Financial services & insurance
  - NPISH
Cyclically sensitive inflation: methods

Using remaining 13 components:
- Maximize the $R^2$ of the regression:

$$\sum_{i=1}^{13} \omega_i \pi_{it}^{BP} = \alpha + \beta(L)x_t^{BP} + v_t \quad \text{s.t.} \quad \sum_{i=1}^{13} \omega_i = 1 \text{ and } 0 \leq \omega_i \leq 1$$

where BP is 6-32 quarter band-pass and $x$ is one or more activity variables

- Base case uses 0-3 lags of the unemployment rate
- computed using 15-year rolling windows

Following figures
- Rolling R2 (unadjusted) and R2 of comparison series
- TV weights and share weights by component
- Cyclically sensitive inflation
Housing ex energy utilities
Housing: energy utilities
Health care (0.16)
Other services (0.09)
Other nondurable goods (0.08)
Food & beverages off-premises (0.08)
Food services & accommodations (0.06)
Motor vehicles & parts (0.04)
Recreation services (0.04)
Gasoline & other energy goods (0.03)
Transportation services (0.03)
Furnishings & household durables (0.03)
Rolling $R^2$s: BP inflation on 0-3 lags of BP unemployment rate

Graph showing the rolling $R^2$ values for different models over time from 1975q1 to 2015q1. The models include:
- R2_roll
- R2_pce_all
- R2_pce_xfe
- R2_pce_xe

The graph illustrates the changes in the $R^2$ values over time for each model.
Rolling PCEExE and CSI (4 quarter inflation)
Recent values: rolling CSI (quarterly inflation)
Summary

1. **There is significant time variation in univariate inflation processes:**
   reduced volatility of trend, so optimal trend estimate has more smoothing

2. **Components seem to have useful but time-varying information:**
   - Considerable changes in component series
   - Some of these changes are measurement changes, incomplete revisions, etc
   - Automatic (hands-free) outlier adjustment useful
   - In particular, there is a case for including food-at-home (shift from PCE-xFE to PCE-xE?)
   - There is no case for including energy in a trend/core estimate

3. **Cyclical behavior varies substantially across components.** Some cyclically synchronized components are:
   - Housing ex energy (rent + OER)
   - Food services & accommodations
   - Recreation services
   - Food & beverages off-premises
   - NPISH (?)
Additional Slides
$\pi_t - \pi_{t-4}$ vs. short-term unemployment rate: CSI

4-qtr change in 4-qtr inflation (CSI) v. short-term un. rate
1960-83 (dots) 1984-99 (diamond) 2000-2016 (triangle)
$\pi_t - \pi_{t-4}$ vs. short-term unemployment rate: PCEExE

4-qtr change in 4-qtr inflation (PCEExE) v. short-term un. rate

1960-83 (dots) 1984-99 (diamond) 2000-2016 (triangle)
Smoothed estimates of $\tau_t$: PCE-all, 17 components (updated 5/23/16)

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<th>Date</th>
<th>PCE-all</th>
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- Actuals are 3-month percentage changes ending final month of quarter (saar).
- Average width of 67% Interval = 1.04 (2008-2014)
### Smoothed estimates of $\tau_\ell$: PCE-xE, PCE-xFE (updated 5/23/16)

#### PCE-xE

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<td>1.75</td>
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</tbody>
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1. Introduction

U.S PCE inflation, headline and core (monthly, MA(3))

---

The chart shows the PCE price index, MA(3) and PCE-PI ex F&E, MA(3) over time from 1960m1 to 2020m1. The data is marked with two lines: green for PCE price index, MA(3) and red for PCE-PI ex F&E, MA(3).
PCE-xFE and Market-based PCE-xFE

- Personal consumption expenditures: Market-based PCE excluding food and energy (chain-type price index)
- Personal Consumption Expenditures Excluding Food and Energy (Chain-Type Price Index)
Core Inflation and Trend Inflation

Eckstein (1981), as quoted in Zeldes (1994) and Wynne (2008) defined core inflation as:

the core rate reflects those price increases made necessary by increases in the trend costs of the inputs to production. The cost increases, in turn, are largely a function of underlying price expectations. These expectations are the results of previous experience, which, in turn, is created by the history of demand and shock inflation.

Bryan and Cecchetti (1994): core inflation is an estimate of trend inflation.

In practice:
• Trend inflation is a time-series smoothing problem
• Core inflation is implemented as cross-sectional averaging
**Time variation in the inflation process: trend estimates**

There has been a large amount of time variation in the processes for headline and core inflation

a) Decrease in relative volatility of trend component since 70s-80s

b) This has the effect of increasing optimal amount of smoothing (trend varies less so use longer smoother to reduce transitory noise)

**PCE-all, qtrly: Trend estimate (smoothed) and 67% bands**

![Graph showing aggregate inflation with trend estimate and 67% bands from 1960 to 2020]
Full-sample posterior for SV processes

PCE-all (blue), PCExE (blue dash), PCExFE (red)

- Trend volatility (above right) has declined sharply from 70s-80s
- for PCE-all, transitory volatility is as high now as in 70s (left)
- but (left)
  - XE transitory volatility has fallen
  - XFE transitory volatility remains low
The components have large time variation in their process

At the level of components, there is even more variation in the process than in aggregate inflation
a) Food at home is especially noteworthy
b) Some of the evolution reflects changes in monetary policy and the economy...
c) But some of the changes are pure measurement effects
   ... a reminder that the evolution of the headline and core processes reflects measurement effects.
d) Technical comment: outlier adjustment is particularly important at the component level