FEDERAL RESERVE BANK *of* CLEVELAND

Post-COVID Inflation Dynamics: Higher for Longer

Randal Verbrugge (FRBC and NBER/CRIW)
Saeed Zaman (FRBC)

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Disclaimers

- All the analysis, views, and conclusions expressed in this paper are those of the authors; they do not indicate concurrence by other members of the research staff of the Federal Reserve Bank of Cleveland or of the Federal Reserve Board, or by the Board of Governors of the Federal Reserve System.

Motivation

- The issues at the forefront of FOMC deliberations
  - What are the tradeoffs going forward? (*How strong is the Phillips curve, and how fast will inflation fall absent a recession?)*

- At the December 2022 FOMC press conference, Chair Powell referred to tripartite decomposition of core PCE inflation
  - To explain the inflation outlook
  - Hence, to explain why the FOMC expects that the federal funds rate will "have to remain high for a time"
- The tripartite decomposition consists of
  - core goods inflation, housing inflation, and core services ex-housing inflation
- December 2022 Survey of Economic Projections (SEP) has:
  - Median projection for core PCE at <u>2.1% by 2025Q4</u>
  - Unemployment rising to peak at <u>4.6%</u>

Motivation

- To assess the plausibility of the SEP forecast (and other counterfactuals), we require a multivariate structural model that jointly estimates the inflation components and unemployment rate
- Crucial to model the Phillips curve relationship appropriately

Phillips curve

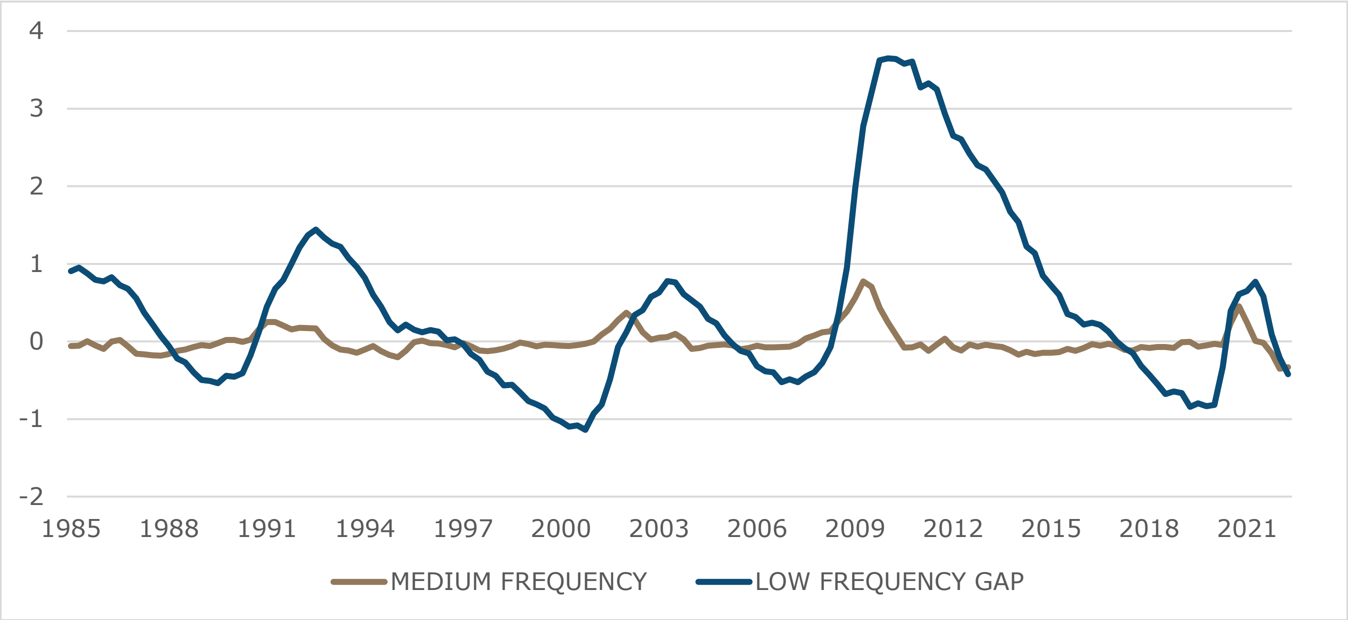
- Recent research has convincingly shown frequency-dependence in the Phillips curve (e.g., Ashley and Verbrugge, 2023)
  - Frequency-dependence is all over the place in macro; e.g., Permanent income hypothesis, monetary policy, etc.

- Unemployment gap (defined as U – U*) is decomposed into
  - Medium-frequency (moderately persistent): fluctuations between 1 and 4 years
  - Low-frequency (persistent): fluctuations greater than 4 years
  - (We drop (insignificant) high-frequency)

- Nonlinearity in Phillips curve:
  - Two unemployment gaps, rather than one
  - Permit asymmetry (different sensitivity to positive vs. negative gaps)

Phillips curve

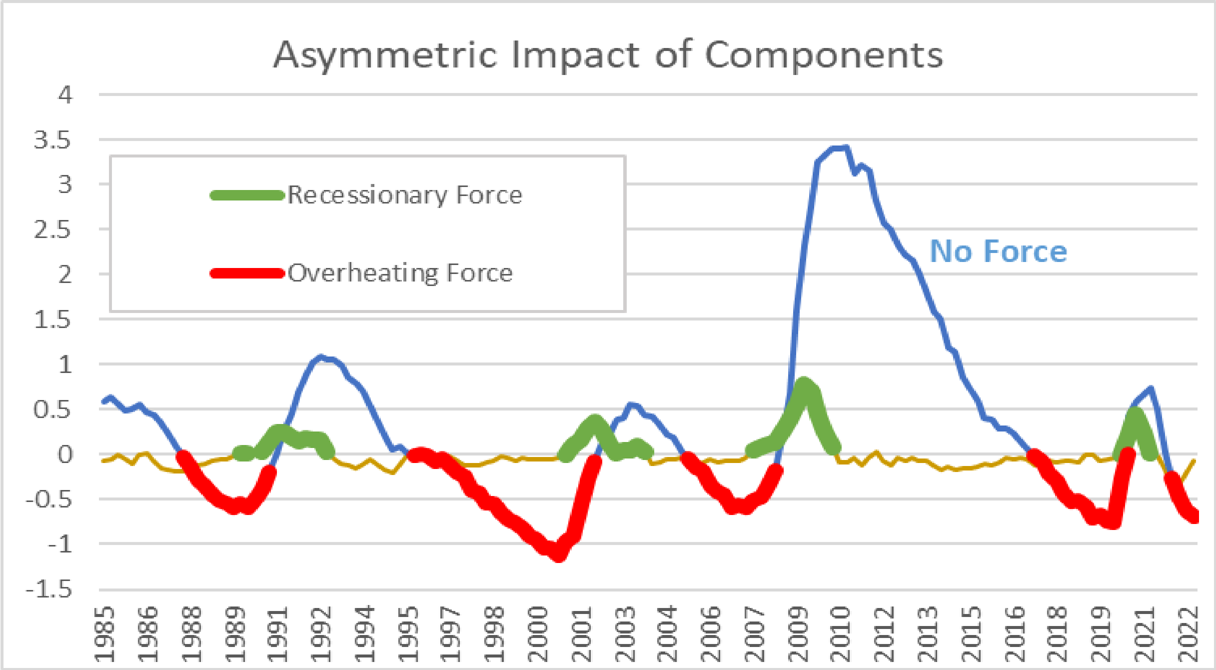
- Two unemployment gap components



Notes:
1) U* from Zaman (2023) but results robust if use U* from CBO.

2) We use <u>jobless unemployment rate</u> from Hall/Kudlyak (2022), since COVID → 20-std-deviation shock to transitory unemployment.

Phillips curve



- Recessionary force: **moderately-persistent** (medium-frequency) movements in the unemployment gap exert a strong **downward** force on inflation – but only when they are positive. Occurs during recession and for a few months later
- Overheating force: **persistent** (low-frequency) movements in the gap exert a strong **upward** force – but only when they are negative, i.e., when economy is overheating
- PC vanishes: positive persistent gap (during recovery) has no influence

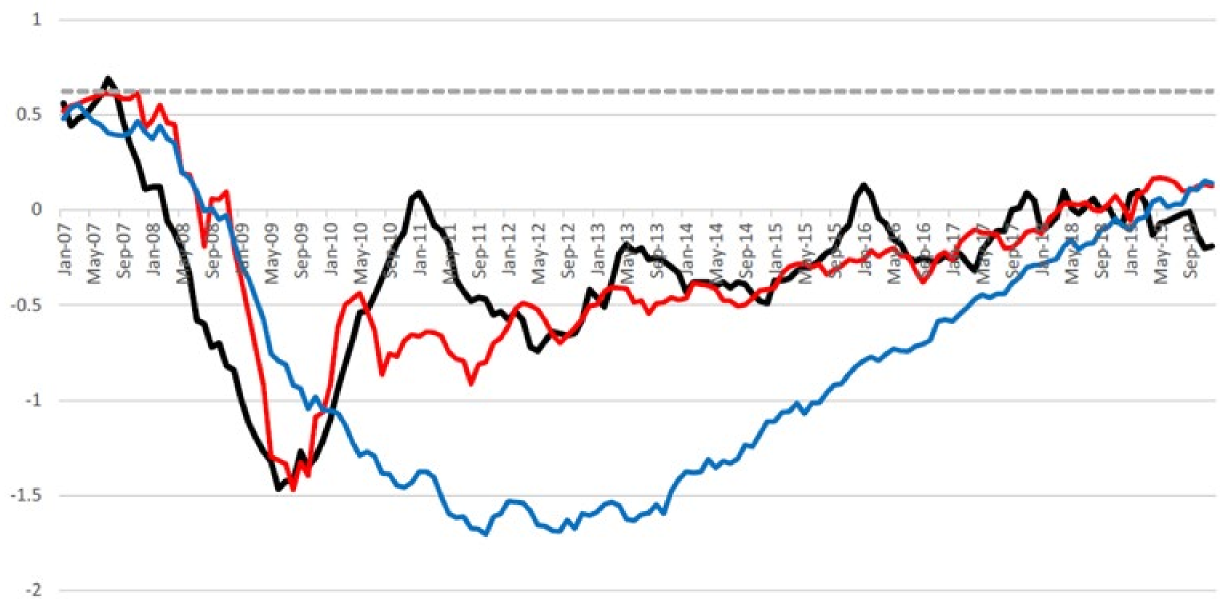
Philips curve

- Ashley and Verbrugge (2023):
  Phillips curve relationship consists of 3 parts, aligned with business cycle
  1. Recessionary force (cf. SW 2010; 2020)
  2. Overheating force
  3. After recovery begins, slack doesn't influence inflation

- Thus, Phillips curve is "Intermittent" and varies across stages of the Business cycle
- We confirm this in our present paper

Should we believe it?

- Modeling such a Phillips curve relationship:
  - Resolves several of the inflation "puzzles", such as missing disinflation (during the financial crisis), missing inflation from 2012 through 2019
  - Impressive out-of-sample forecasting properties:
    - Conditional forecast of (trimmed-mean PCE) inflation using no inflation data after 2006, but conditioned on unemployment rate, does a very reasonable job capturing the evolution of inflation: actual core inflation (black), UCSV (grey), conventional PC (blue), nonlinear PC model (red)



What we do in this paper

- Implement a novel nonlinear structural VAR model featuring
  - *Frequency-dependence* and *asymmetric* Phillips curve
  - Each of three core PCE components (core goods, housing, core services ex housing) is allowed to have its own Phillips curve
  - Include a variable capturing **supply shocks** (important)
  - Identification using the data-determined approach of Swanson and Granger (1997; JASA)
  - Reliable? Assess the out-of-sample forecast accuracy

- Use the SVAR model to do counterfactual exercises
  - Conditional forecasts of inflation on hypothetical paths of the unemployment rate
  - Assess the plausibility of the inflation forecast from Federal Reserve's Summary of Economic Projections December 2022
  - Perform simple welfare analysis for the various counterfactuals

Main Findings

- All three inflation components have high (though differing) persistence, and varying nonlinear Phillips curve relationships
- Estimated impulse responses reveal *interesting nonlinearities*
  - **Housing inflation** is very persistent, responds strongly to both recessionary force and overheating force
  - **Core services ex-housing inflation** is very persistent; responds only modestly to the recessionary force, but strongly to the overheating force
  - **Core goods inflation** responds marginally to recessionary force only
- Forecast accuracy competitive to hard to beat benchmarks
- Will inflation hit 2% by the end of 2025 without a recession (Dec. SEP)?
  - According to the model, **inflation will not hit 2%** unless there is a recession, but such a recession is not ideal based on a simple reduced-form welfare analysis

Model details: variables

- We use quarterly data spanning 1985-2022, though estimate model parameters using pre-COVID data, i.e., 1985-2019
- Three components of core PCE inflation
- Two components of the (jobless) unemployment rate
- Supply shocks variable: PPI-IG
  (We show mostly driven by supply shocks)
- Thus, our model consists of 6 variables:
  - 3 core PCE variables
  - 2 unemployment components
  - PPI-IG
- Forecasts of core PCE inflation are computed by combining the forecasts of the three inflation components using their share weights

Model details: Approach to reduced-form specification

- Want good forecasting properties, so:
  - Equation-by-equation specification
  - Allow 5 lags of own variable, 4 lags of other variables, allow for sign asymmetry in gap components
  - Penalize extra coefficients: step-down testing
  - Bias-adjust coefficients as in Kilian (1998)

Model details: Inflation equations and PPI equation

$$\pi_t^{CoreG} = \alpha^{CoreG} + \phi_1^{CoreG}\pi_{t-1}^{CoreG} + \phi_2^{CoreG}\pi_{t-4}^{CoreG} + \phi_5^{CoreG}\pi_{t-5}^{CoreG} + \\ + \beta_1^{CoreG}\pi_{t-3}^{PPI} + \lambda^{CoreG}u_{t-4}^{+medfreq} + \psi I^{1995} + e_t^{CoreG}$$

$$\pi_t^{MServXH} = \alpha^{MServXH} + \gamma_1^{MServXH}\pi_{t-1}^{MServXH} + \gamma_2^{MServXH}\pi_{t-2}^{MServXH} + \gamma_5^{MServXH}\pi_{t-5}^{MServXH} + \\ + \lambda^{MServXH}u_{t-1}^{+medfreq} + \mu^{MServXH}u_{t-1}^{-lowgap} + e_t^{MServXH}$$

$$\pi_t^{Hous} = \alpha^{Hous} + \sum_{j=1}^{5}\eta_j^{Hous}\pi_{t-j}^{Hous} + \lambda^{Hous}u_{t-1}^{+medfreq} + \mu^{Hous}u_{t-4}^{-lowgap} + e_t^{Hous}$$

$$\pi_t^{PPI} = \alpha^{PPI} + \sum_{j=1}^{4}\beta_j^{PPI}\pi_{t-j}^{PPI} + \delta\Delta u_{t-1}^{medfreq} + e_t^{PPI}$$

Model details: Inflation equations and PPI equation

$$\pi_t^{CoreG} = \alpha^{CoreG} + \phi_1^{CoreG}\pi_{t-1}^{CoreG} + \phi_2^{CoreG}\pi_{t-4}^{CoreG} + \phi_5^{CoreG}\pi_{t-5}^{CoreG} + \\ + \beta_1^{CoreG}\pi_{t-3}^{PPI} + \lambda^{CoreG} u_{t-4}^{+medfreq} + \psi I^{1995} + e_t^{CoreG}$$

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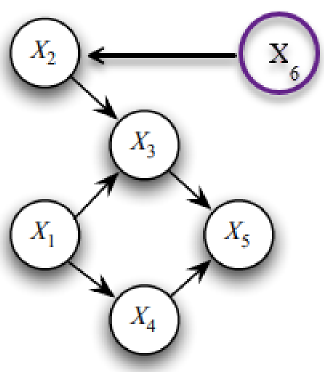
$$\pi_t^{Hous} = \alpha^{Hous} + \sum_{j=1}^{5} \eta_j^{Hous}\pi_{t-j}^{Hous} + \lambda^{Hous} u_{t-1}^{+medfreq} + \mu^{Hous} u_{t-4}^{-lowgap} + e_t^{Hous}$$

$$\pi_t^{PPI} = \alpha^{PPI} + \sum_{j=1}^{4} \beta_j^{PPI}\pi_{t-j}^{PPI} + \delta\Delta u_{t-1}^{medfreq} + e_t^{PPI}$$

Model details: Identification

- Next step is to identify the SVAR…

$$\mathbf{A}Z(t) = B(L)Z(t) + u(t),\ u(t)\ \text{uncorrelated.}$$



$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

One example of a model, i.e., identifying non-zero entries in A.

Model details: Identification

- Swanson and Granger [SG] (JASA, 1998).
  Key insight: data themselves restrict the class of admissible models ("causal discovery")

- After set of admissible models is identified, only then do you need to use theory, timing restrictions, etc.

SG Method: causal discovery

- Compute, all pairwise correlations of reduced-form residuals, and examine their statistical significance
- If $e_j \perp e_k$, then $A(j,k) = 0 = A(k,j)$*
- If e_j and e_k are correlated, then, test partial correlation: if e_j and e_k are correlated, but uncorrelated once you control for e_l then $A(j,k) = 0 = A(k,j)$
- Etc. (large literature at this point, but relatively unknown in economics)
- Tremendous winnowing of models: in our case, from >1 million models** to just 8.

*Requires a weak 'faithfulness' assumption

**Squires and Uhler, 2022

SG Method: causal discovery

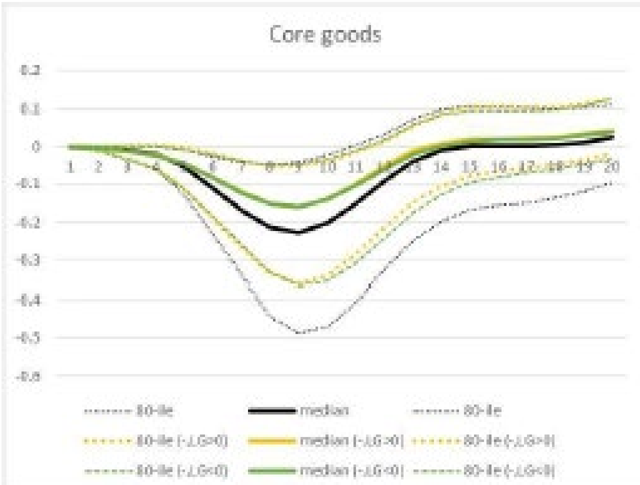
- Use economic theory: from 8 models to 1 model
  - PPI → causes Core goods inflation
  - PPI → causes Core services ex-housing
  - Core services ex-housing → causes Housing
  - U(medfreq) → causes U(lowfreq)
- Our assumptions lead to the following loading matrix A (only nonzero entries are indicated)

$$AM_t = \begin{bmatrix} 1 & & & & & \\ -a_{21} & 1 & & & & \\ -a_{31} & & 1 & & & \\ & & -a_{43} & 1 & & \\ & & & & 1 & \\ & & & & -a_{65} & 1 \end{bmatrix} \begin{bmatrix} \pi_t^{PPI} \\ \pi_t^{CoreG} \\ \pi_t^{MNHServ} \\ \pi_t^{Hous} \\ u_t^{medfreq} \\ u_t^{lowgap} \end{bmatrix}$$

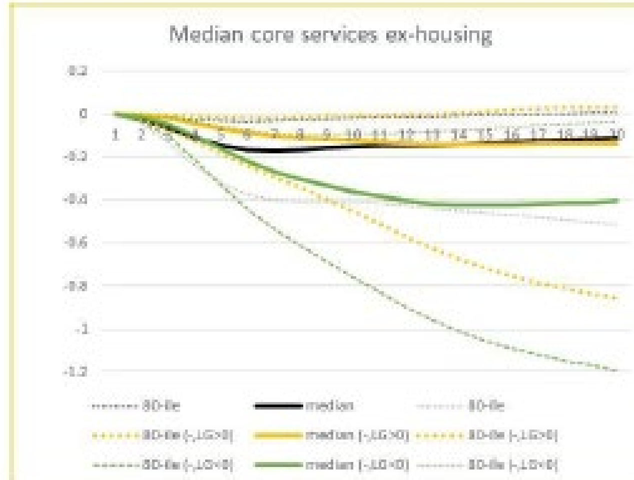
Generalized IRFs

- To construct IRFs, use bootstrap-upon-bootstrap approach, with bias correction and variance correction
- IRFs are nonlinear, so need to decide initial conditions and also positive or negative shock.
  - E.g., for shocks to **medium-frequency** unemployment rate:
    - One IRF is for a positive shock, when the component is already positive.
    - When shock is negative, medium-frequency doesn't matter (directly). But shock still has an impact because it induces the low-frequency gap to move. So:
    - negative shock when low-frequency gap is positive.
    - negative shock when low-frequency gap is negative.

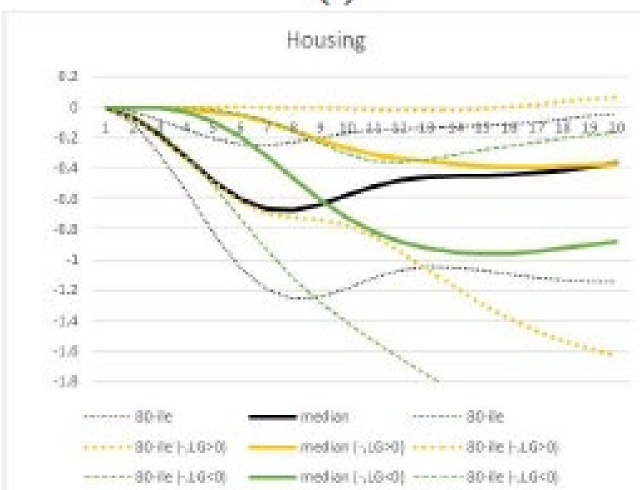
IRFs to medium-frequency unrate shock



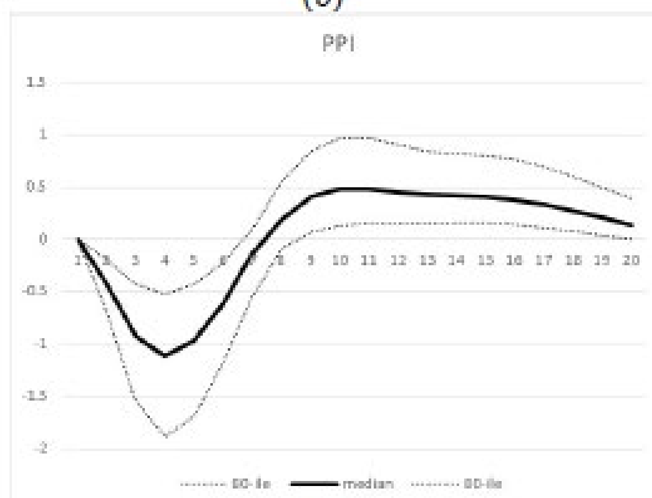
(a)



(b)



(c)



(d)

Forecast accuracy

Table 1: Point Forecast Accuracy Comparison

Mean Squared Error (MSE): Sample 2007-2019Q3		
(a) Core PCE Inflation (4Q-trailing rate, %)		
Models	Horizon	
	One-year out (h=4Q)	Two-years out (h=8Q)
MSE of Random Walk (RW)	0.23	0.39
Relative MSE, relative to RW		
VZ VAR (conditional on UR)	0.84	0.68**
VZ VAR (unconditional)	0.96	0.60**
UCSV (Stock and Watson)	1.17	0.92
(b) Unemployment rate (%)		
MSE of AR4 model	1.14	4.20
Relative MSE, relative to AR4		
VZ VAR (unconditional)	0.94	0.94
AR1 model	1.52*	1.32

Notes: The numbers reported in the first row of each panel are the mean squared error (MSE) from the benchmark model, RW in the case of core inflation, and AR4 in the case of the unemployment rate. The rows below the first row are ratios that report relative MSEs (relative to the benchmark model). Thus, a ratio of more than one indicates that the benchmark model is more accurate on average than the model being compared. The forecast evaluation is based on an expanding window of estimation spanning the period 2007Q1 through 2019Q3. The estimation start period is 1985Q1. A * indicates statistical significance up to 10% level, and a * indicates statistical significance at the 5% level,based on Diebold-Mariano-West test.

We estimate **50** coefficients. And still, out of sample, our SVAR is competitive with standard benchmarks.

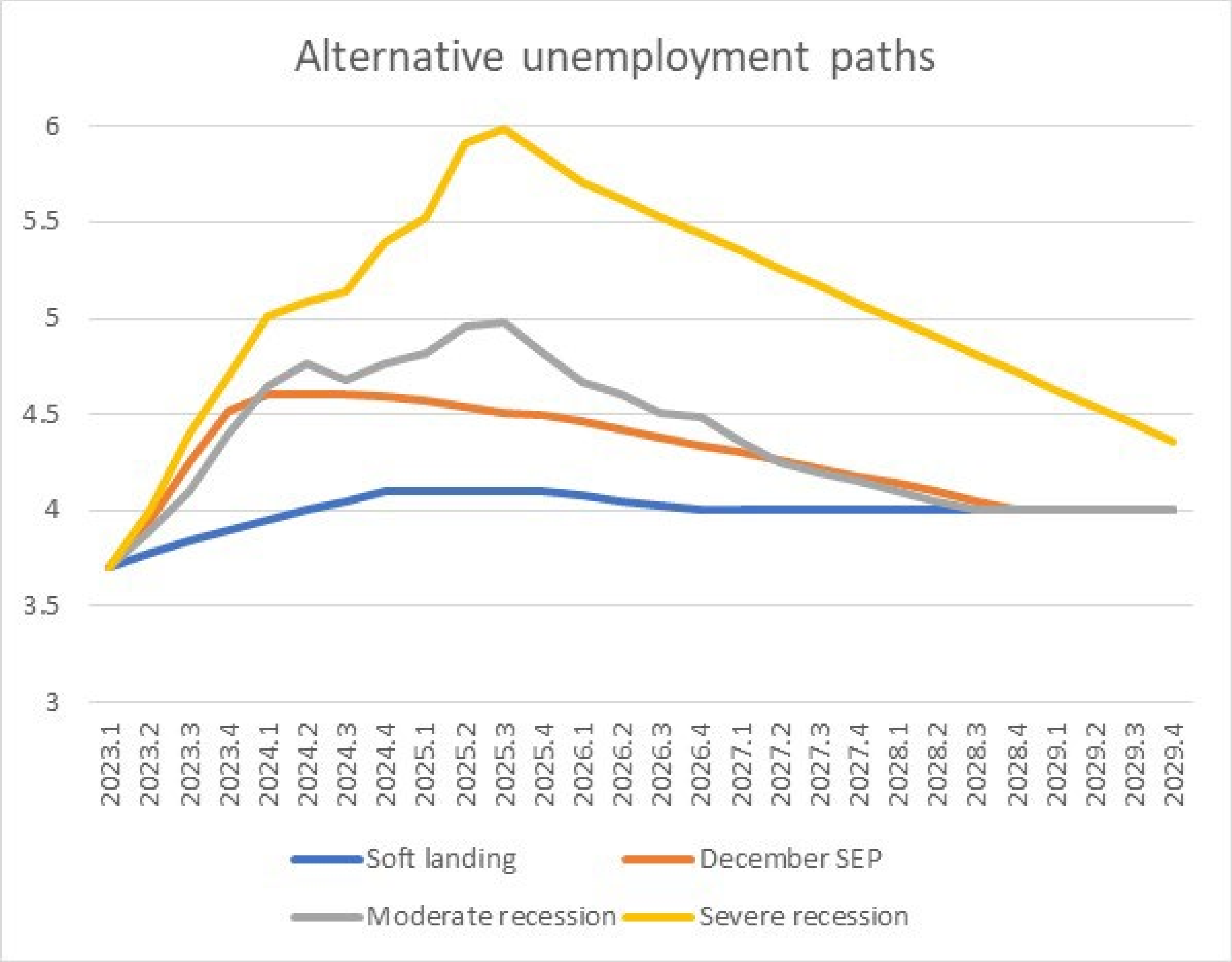
Note: inflation forecast gains are episodic, as one might expect.

Counterfactual forecasts (2023q1 onwards)

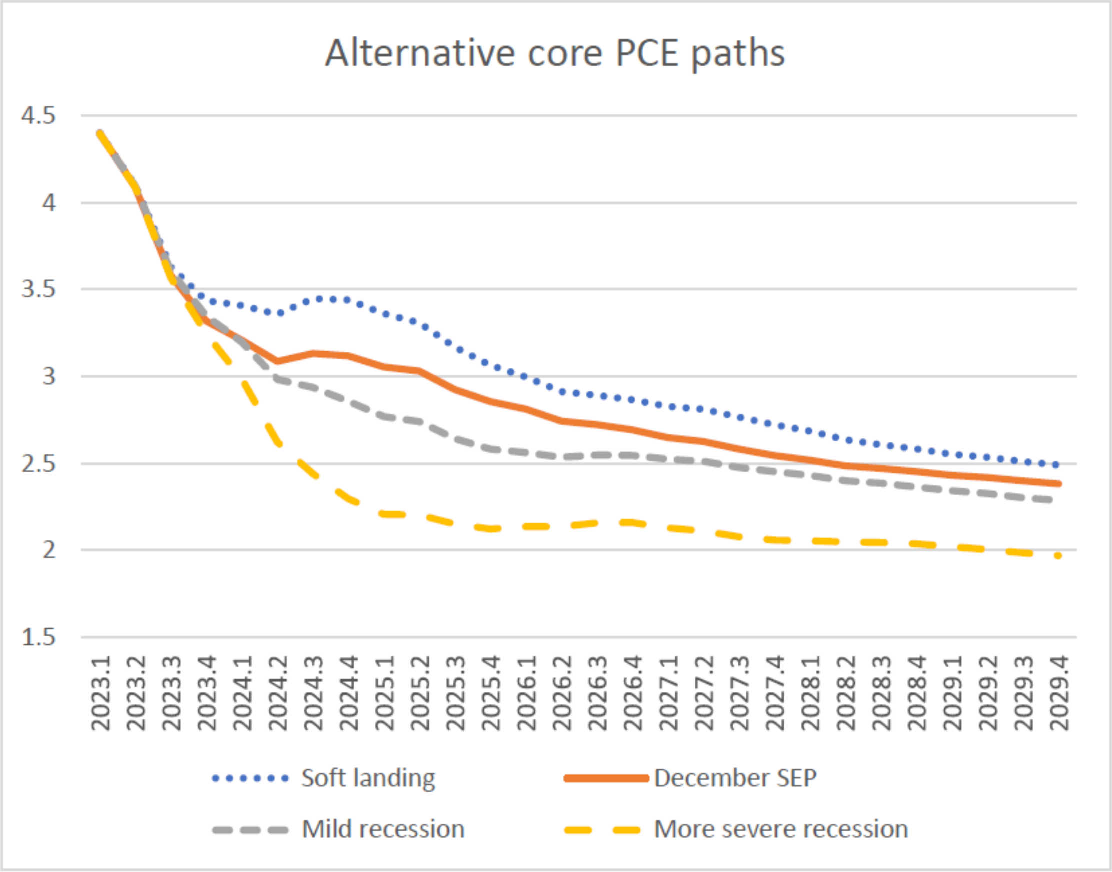
- Generate multiple forecasts for inflation, all of which are conditional on various hypothetical paths for the unemployment rate
  - December SEP: UR increases by 0.9 percentage point to 4.6%
  - Soft Landing: UR path informed from the June 2022 SEP (similar to September 2023 SEP), has UR peaking at 4.1% by 2024Q4
  - Moderate Recession: UR path that mimics the 2001 recession; UR is projected to top at 5.0% in 2025Q3
  - Severe Recession: (inspired by the Summers/Ball/Leigh/Mishra) conditions on a path for UR that peaks at 6.9% in 2025Q3

- In all counterfactual forecasts, to improve forecast accuracy, we condition on short-term information/nowcasts

Four alternative unemployment paths



Implied inflation forecasts



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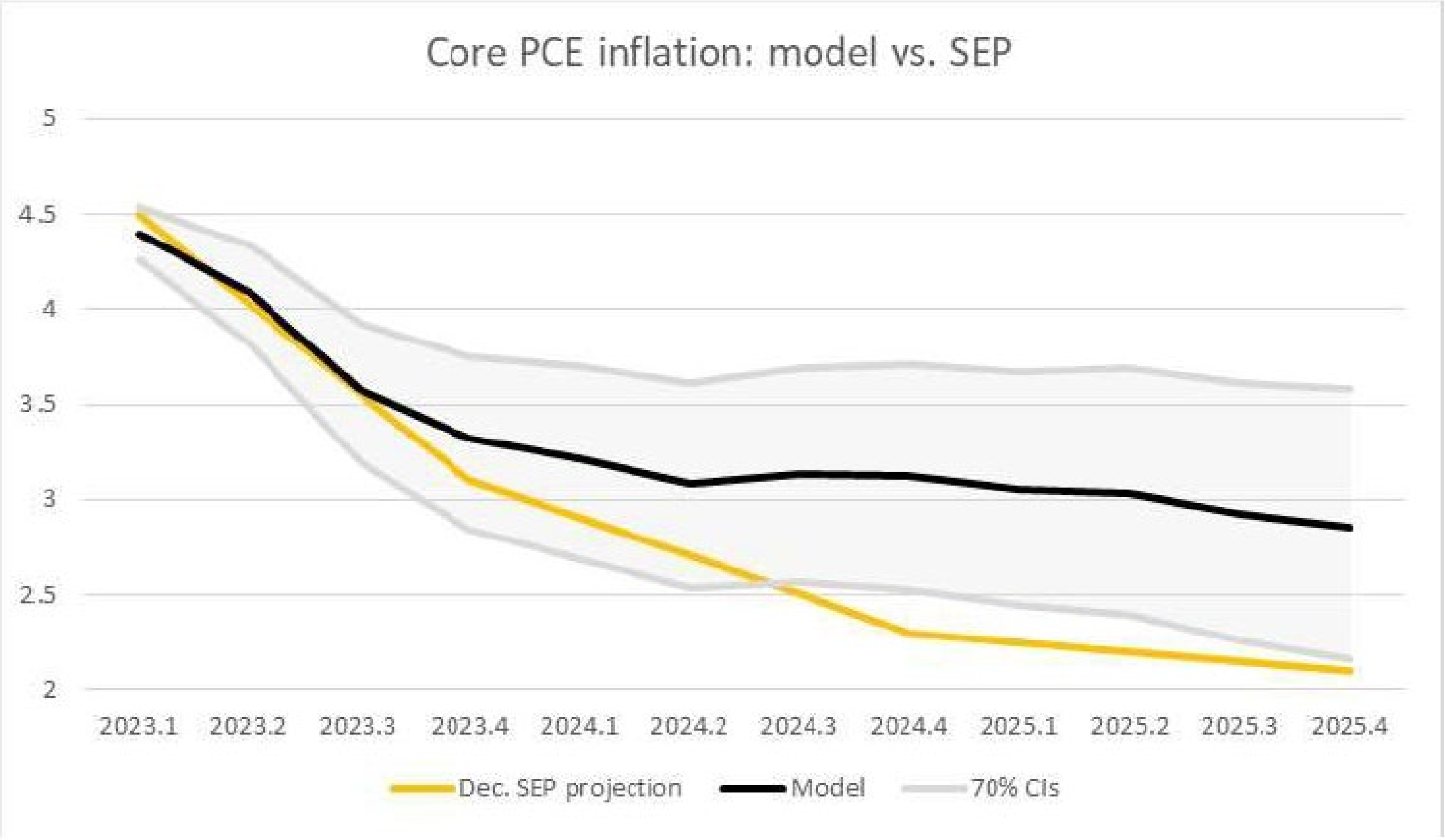
Is SEP inflation forecast consistent with SEP unemployment forecast? Er, no.



2.9%

While Dec. SEP path for unemployment does provide some recessionary force, it is not nearly enough to pull inflation down to 2.1% by end of 2025.

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Simple Reduced-form Welfare Analysis

- Simple welfare analysis based on a quadratic loss function*
  - Penalizes quarterly deviations of inflation from 2%
  - Penalizes quarterly deviations of unemployment from 4 percent (the FOMC/SEP's estimate of the longer-run level of unemployment)

$$L\{u_t, \pi_t\}_{t=t_1}^{t_2} = \sum_{s=0}^{t_2-t_1}\left[(1-w)\left(u_{t_1+s}-u_t^*\right)^2 + w\left(\pi_{t_1+s}-\pi^*\right)^2\right]$$

$$u_t^* = 4.0 \text{ and } \pi^* = 2.0$$

$$t_1 = 2023\text{Q1 to } t_2 = 2029\text{Q4}$$

*In some contexts, such loss functions are a second-order Taylor series approximation to the expected utility of the economy's representative household (Woodford, 2002).

Simple Reduced-form Welfare Analysis

Table: Welfare Losses

w	*Soft landing*	*December SEP*	*Mild recession*	*More severe recession*
0.10	7.35	8.05	25.74	78.32
0.19	10.36	10.09	25.53	72.09
0.25	12.36	11.46	25.39	67.93
0.50	20.71	17.14	24.79	50.62
0.75	29.06	22.82	24.20	33.31
0.81	31.07	24.18	24.06	29.16
0.90	34.07	26.23	23.84	22.93

- For equal weights on inflation and unemployment, favors the 'Higher for Longer' December SEP unemployment rate path
- If the weight on inflation is low, it prefers the Soft Landing
- If the weight on inflation is high, it prefers the Moderate Recession
- Only for very high weight for inflation, it prefers more Severe Recession

Summary

- Implement a novel nonlinear structural VAR model that is identified using data-based method of Swanson & Granger
- For each of the three components of core PCE, the Phillips curve relationship is found to be two-dimensional:
  - Negative low frequency gap (overheating force)
  - Positive Medium frequency (recessionary force)
  - After recovery begins, slack does not influence inflation
- Inflation is very persistent. Absent recessionary or overheating force, inflation moves very slowly toward target
  - In US, after GR, took 6 years to move just ½ ppt
  - Implies that anchored inflation expectations exert only a modest/"slow" force on inflation

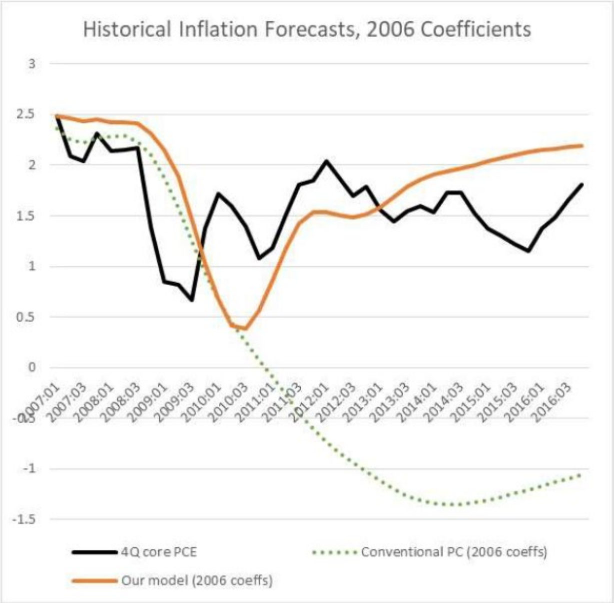
Summary

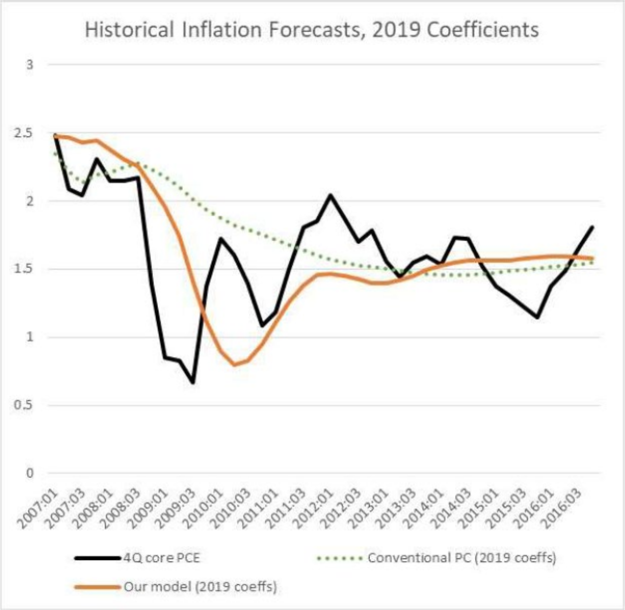
- Inflation will not come down below 3% before 2025Q4 without a recession
  - Economy slowing alleviates upward pressure but does not provide downward pressure
  - Model provides policymakers with a <u>reliable</u> sense of tradeoffs
  - Linear conventional PCs which effectively average the three distinct relationships across differing portions of the business cycle will underestimate the
    - Upward force on inflation being exerted by the hot labor market
    - Downward force on inflation from a recession

- Simple welfare analysis prefers December SEP path (for unemployment)

Extra slides

2007-2016, recursive forecast, vs. conventional Phillips curve model (estimated in 2019)





Persistence and memory