

# A Model of the Fed's View on Inflation

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# The Federal Reserve's View

“Inflation is characterized by an underlying trend that has been essentially constant since the mid-1990s; .... Theory and evidence suggest that this trend is strongly influenced by inflation expectations that, in turn, depend on monetary policy. In particular, the remarkable stability of various measures of expected inflation in recent years presumably represents the fruits of the Federal Reserve's sustained effort since the early 1980s to bring down and stabilize inflation at a low level. The anchoring of inflation expectations ... does not, however, prevent actual inflation from fluctuating from year to year in response to the temporary influence of movements in energy prices and other disturbances. In addition, inflation will tend to run above or below its underlying trend to the extent that resource utilization—which may serve as an indicator of firms' marginal costs—is persistently high or low.”

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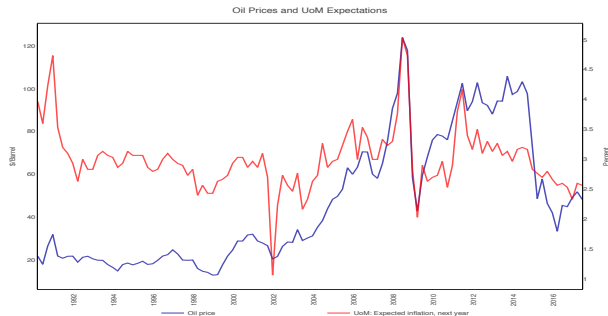
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## Puzzles in Inflation:

- **Weak empirical evidence** on the PC
- Inflation can be **forecast** by statistical processes **unrelated to slack**
- Evidence of the **flattening** (or **disappearance** of the Phillips Curve)
- **Missing deflation...**
- Disanchoring of consumers' expectation due to **oil shocks**

# The Role of Oil Shocks in Inflation Expectations

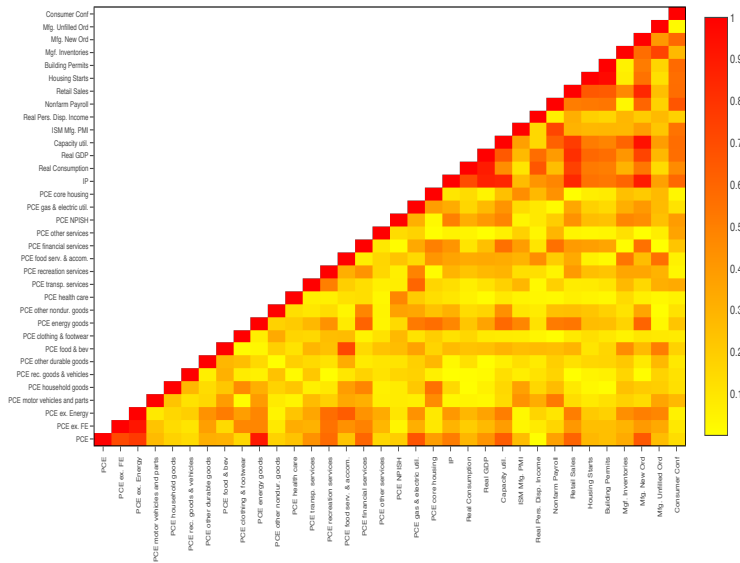
Coibion, Gorodnichenko (2015)



- **Household** (and firms) expectations may be **not fully anchored**
- ... and can respond to **oil and commodity** price changes
- gasoline prices are among the most **visible prices**
- ... and may follow a **global demand cycle**

# Weak Correlation Prices and Quantities

Abs. correlation between real data (in YoY, %) and  $\Delta^* \pi^*$





# The Phillips curve: a Needle in the Haystack?



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# **A Stylised Rational Expectations Model**



# Stylised Rational Expectations Model

$$\begin{aligned}y_t &= \mu_t^y + \hat{\psi}_t + \psi_t^y \\ \pi_t &= \mu_t^\pi + \delta_\pi \hat{\psi}_t + \psi_t^\pi \\ \mathbb{E}_t[\pi_{t+h}] &= \mathbb{E}_t[\mu_{t+h}^\pi + \delta_\pi \hat{\psi}_{t+h} + \psi_{t+h}^\pi]\end{aligned}$$

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- $\mu_t^y$  and  $\mu_t^\pi$  are independent random walk trends

$$\begin{aligned}\mu_t^y &= \bar{\mu}^y + \mu_{t-1}^y + u_t^y \\ \mu_t^\pi &= \mu_{t-1}^\pi + u_t^\pi\end{aligned}$$

- **Trend inflation** relates to long-run forecast for inflation

$$\lim_{h \rightarrow \infty} \mathbb{E}_t[\pi_{t+h}] = \mu_t^\pi$$

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- $\hat{\psi}_t$  is the **output gap** reflected in a (hybrid) the **Phillips curve**

$$\hat{\pi}_t = \sum_{i=1}^2 \delta_i \hat{\pi}_{t-i} + \beta \mathbb{E}_t[\hat{\pi}_{t+1}] + \kappa \hat{y}_t + v_t$$

- A **stochastic cycle** – AR(2) with complex roots

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- $\psi_t^y$  and  $\psi_t^\pi$  are other idiosyncratic disturbances

# Reduced Form Representation – Trend & Cycle

$$\begin{pmatrix} y_t \\ \pi_t \\ \mathbb{E}_t [\pi_{t+1}] \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ \delta_\pi & 1 \\ \delta_{exp,1} + \delta_{exp,2}L & 1 \end{pmatrix} \begin{pmatrix} \hat{\psi}_t \\ \mu_t^\pi \end{pmatrix} + \begin{pmatrix} \mu_t^y \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} \psi_t^y \\ \psi_t^\pi \\ 0 \end{pmatrix}$$

1. Can accommodate different specifications for the Phillips Curve
2. An AR(1)  $\hat{\psi}_t$  would be the solution to a **purely forward** looking New-Keynesian Phillips Curve
3. It also nests the **backwards looking** ‘Old-Keynesian’ Phillips curve connecting output gap and prices

## **Bringing the model to the data**

# Rich Inflation Dynamics

- ① **Heterogenous dynamics** along the **business cycle**  
⇒ Lagged relations prices-slack
- ② Labour market dynamics along the **business cycle**  
⇒ **Okun's law** connecting slack-unemployment
- ③ Energy price movement impact CPI directly

$$\pi_t = \pi_t^c + v_1 \pi_t^{en} + v_2 \pi_t^{food}$$

⇒ Difference between CPI **Headline** and **Core**

- ④ **Non-fundamental fluctuations**  
⇒ Oil shocks perturb inflation via expectations
- ⑤ Deviations from full-information RE  
⇒ **Bias**, disanchoring, ...

# Model Assumptions

$$\begin{pmatrix} y_t \\ e_t \\ u_t \\ oil_t \\ \pi_t \\ \pi_t^c \\ F_t^{uom} \pi_{t+4} \\ F_t^{spf} \pi_{t+4} \end{pmatrix} =$$



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- Stationary idiosyncratic disturbances... and idiosyncratic trends

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$$\begin{pmatrix} y_t \\ e_t \\ u_t \\ oil_t \\ \pi_t \\ \pi_t^c \\ F_t^{uom} \pi_{t+4} \\ F_t^{spf} \pi_{t+4} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ \delta_{e,1} + \delta_{e,2}L & 0 & 0 \\ \delta_{u,1} + \delta_{u,2}L & 0 & 0 \\ 0 & 1 & 0 \\ \delta_{\pi,1} + \delta_{\pi,2}L & \gamma_{\pi,1} + \gamma_{\pi,2}L & 1 \\ \delta_{\pi^c,1} + \delta_{\pi^c,2}L & \gamma_{\pi^c,1} + \gamma_{\pi^c,2}L & 1 \\ \delta_{uom,1} + \delta_{uom,2}L + \delta_{uom,3}L^2 & \gamma_{uom,1} + \gamma_{uom,2}L & 1 \\ \delta_{spf,1} + \delta_{spf,2}L + \delta_{spf,3}L^2 & \gamma_{spf,1} + \gamma_{spf,2} & 1 \end{pmatrix} \begin{pmatrix} \hat{\psi}_t \\ \psi_t^{EP} \\ \mu_t^\pi \end{pmatrix} + \begin{pmatrix} \psi_t^y \\ \psi_t^e \\ \psi_t^u \\ \psi_t^{oil} \\ \psi_t^\pi \\ \psi_t^{\pi^c} \\ \psi_t^{uom} \\ \psi_t^{spf} \end{pmatrix} + \begin{pmatrix} \mu_t^y \\ \mu_t^e \\ \mu_t^u \\ \mu_t^{oil} \\ \mu_t^\pi \\ \mu_t^{\pi^c} \\ \mu_t^{uom} \\ \mu_t^{spf} \end{pmatrix}$$

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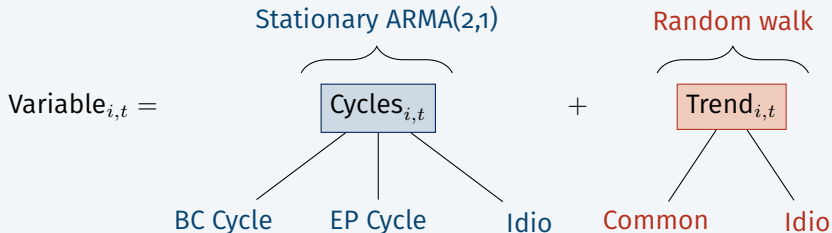
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# The Model in a Nutshell



- Stationary Cycles

$$\begin{pmatrix} \psi_t^j \\ \psi_t^{*j} \end{pmatrix} = \rho^j \begin{pmatrix} \cos(\lambda^j) & \sin(\lambda^j) \\ -\sin(\lambda^j) & \cos(\lambda^j) \end{pmatrix} \begin{pmatrix} \psi_{t-1}^j \\ \psi_{t-1}^{*j} \end{pmatrix} + \begin{pmatrix} v_t^j \\ v_t^{*j} \end{pmatrix}, \quad \begin{pmatrix} v_t^j \\ v_t^{*j} \end{pmatrix} \sim \mathcal{N}(0, \varsigma_j^2 I_2)$$

- Unit Root Trends (w/ or w/o drift)

$$\mu_t^j = \mu_0^j + \mu_{t-1}^j + u_t^j, \quad u_t^j \sim \mathcal{N}(0, \sigma_j^2).$$

# Bringing the Model to the Data

Variable	Transformation	Loads on		
		BC Cycle	EP Cycle	Common Trend
Gross Domestic Product	Levels	✓	✗	✗
Employment	Levels	✓	✗	✗
Unemployment Rate	Levels	✓	✗	✗
WTI Spot Oil Price	Levels	✗	✓	✗
CPI: All Items	YoY	✓	✓	✓
Core CPI	YoY	✓	✓	✓
UoM: Expected Inflation	Levels	✓	✓	✓
SPF: Expected Inflation	Levels	✓	✓	✓

**Sample:** Quarterly, Q1-1984 to Q2-2017



# The Modelling of Expectations

## Deviation from Textbook Rational Expectation Model

We model agents' (survey) expectations

$$F_t^* \pi_{t+4} = \mu_t^\pi + \delta_*(L) \hat{\psi}_t + \gamma_*(L) \psi_t^{EP} + \psi_t^* + \mu_t^*$$

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Allow for:

1. Expectational oil disturbances (**transitory disanchoring**)

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Allow for:

1. Expectational oil disturbances (**transitory disanchoring**)
2. Non-classical **measurement error** in the variables
3. Time varying bias in expectations (**permanent disanchoring**)

# Bayesian Estimation

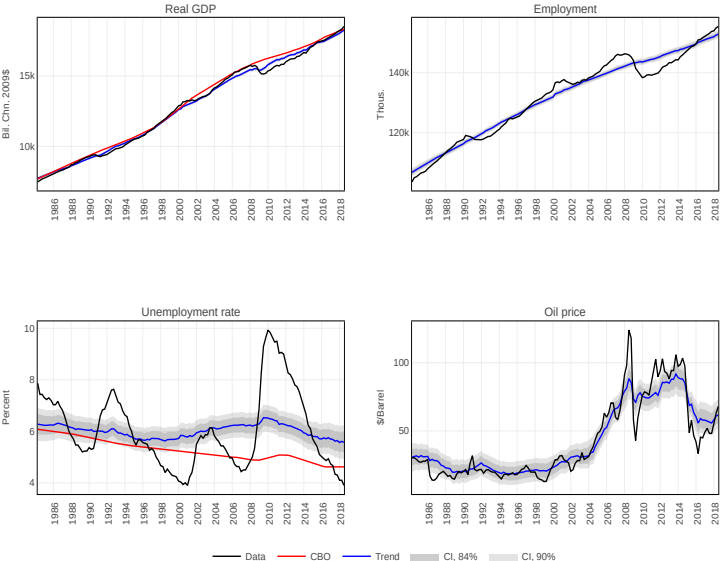
## Metropolis-Within-Gibbs Algorithm

The algorithm is structured in two blocks (**priors are diffuse or weakly informative**):

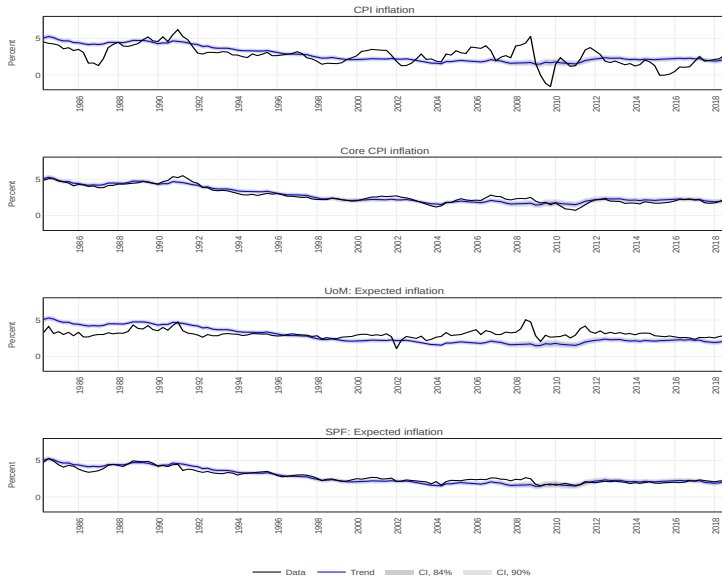
- The **first block** uses a Metropolis step for the **estimation of the state-space parameters**
- The **second block** uses a Gibbs step to draw the **unobserved states** conditional on the model parameters

# **Trends & Cycles in US Inflation**

# Output Potential, Equilibrium Employment

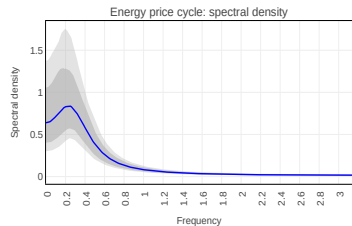
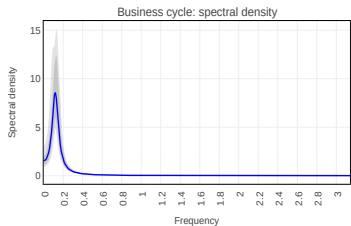
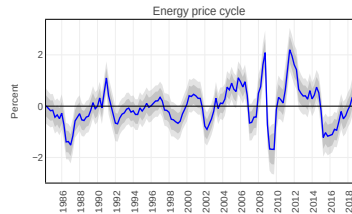
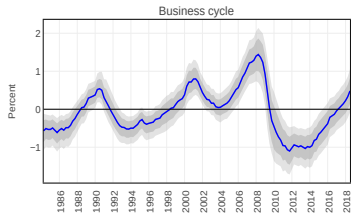


# Common Trend and Inflation



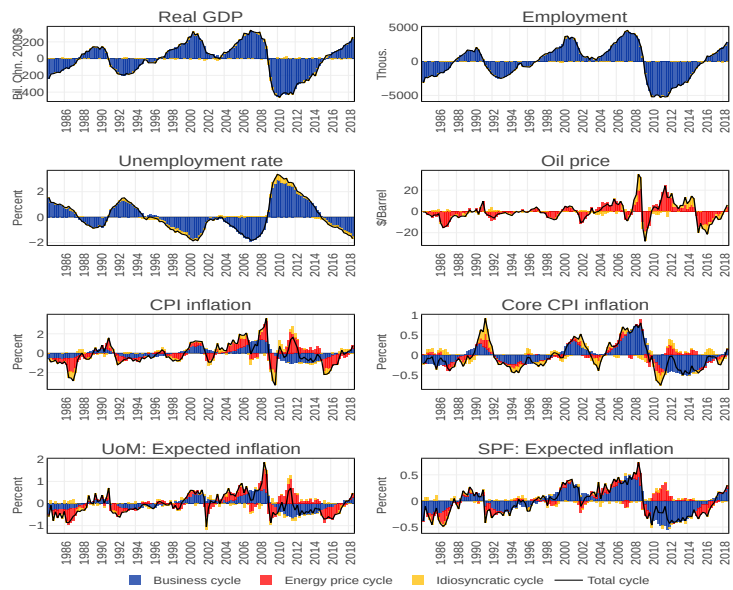


# Common Cycles



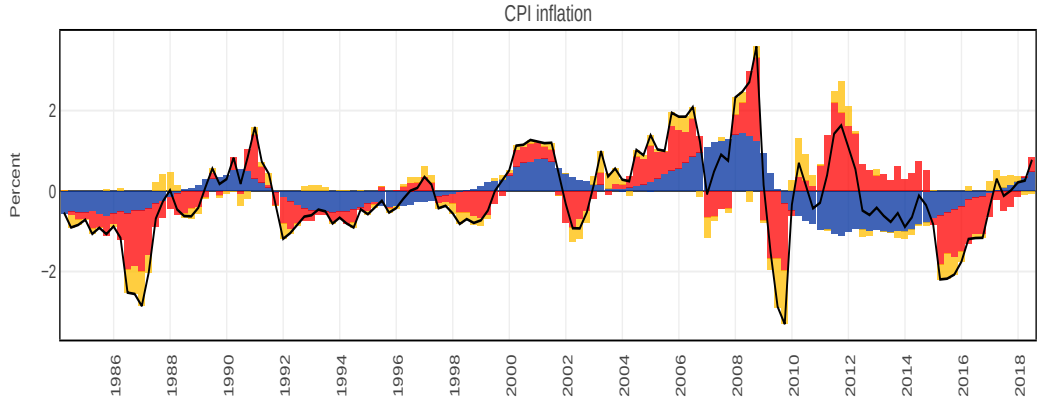
— Median    — CI, 90%    — CI, 84%

# Historical Decomposition of the Cycles



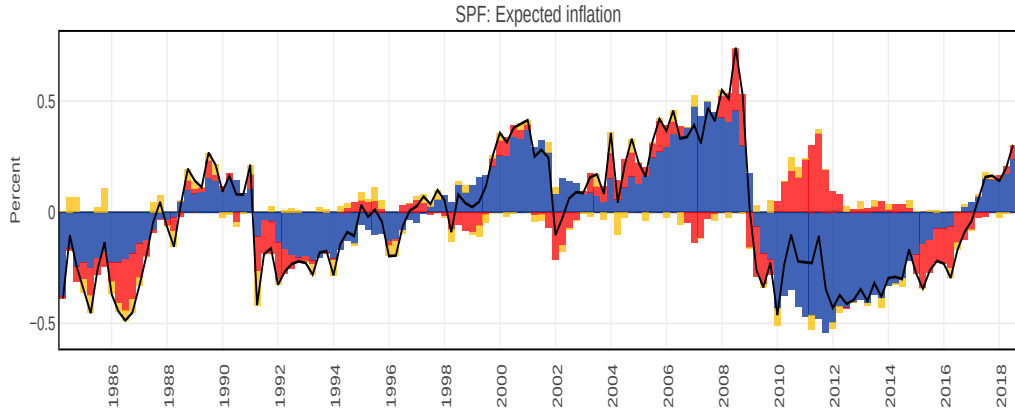
# Historical Decomposition of the Cycles

## Headline CPI



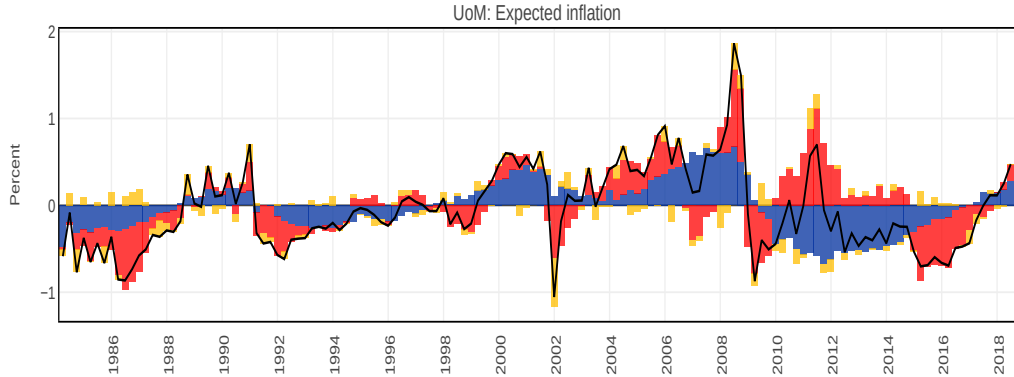
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## Survey of Professional Forecasters



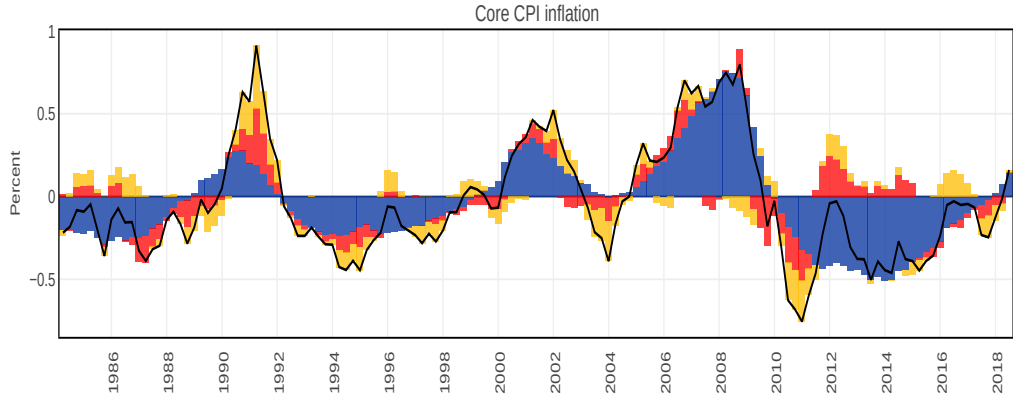
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University of Michigan Consumers Survey

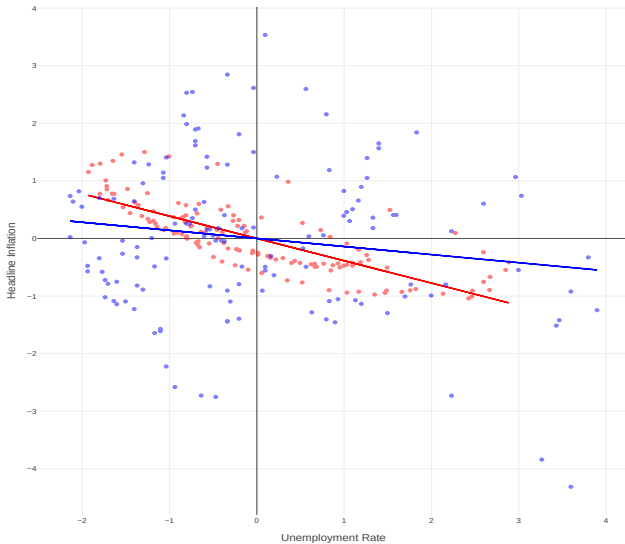


# Historical Decomposition of the Cycles

## Core CPI



# The Slope of the Phillips Curve

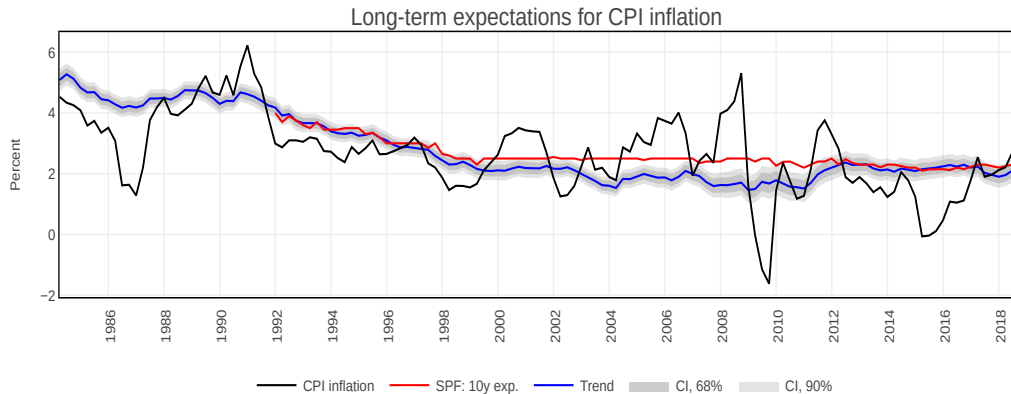


Phillips Curve slope

- Blue line is **-0.14**
- Red line is **-0.39**

# Common Inflation Trend and 10-year Expectations

## The Trend in Inflation

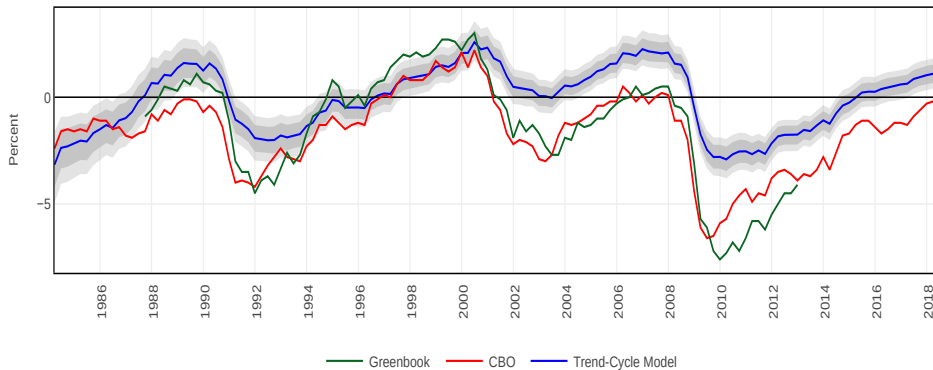




# Output Gap

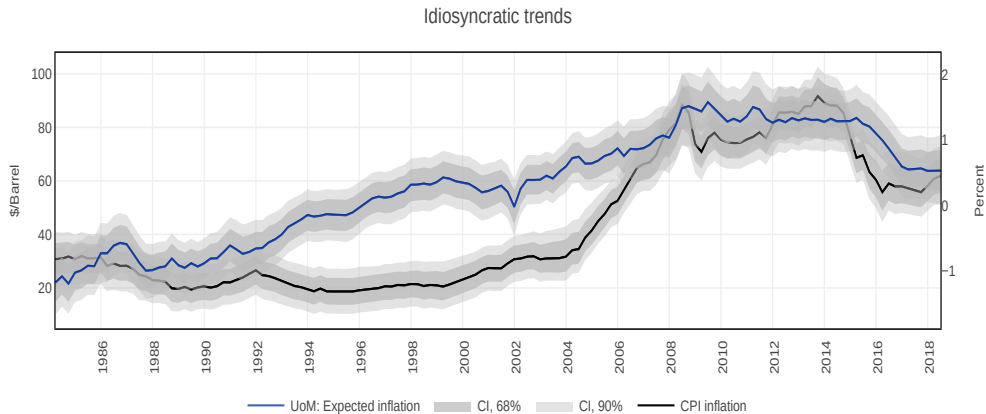
## How Deep a Recession?

Output gap as a percentage of potential GDP



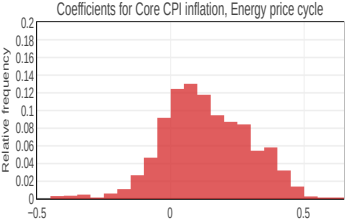
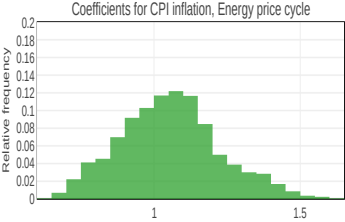
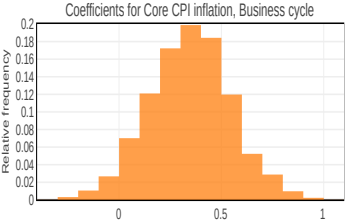
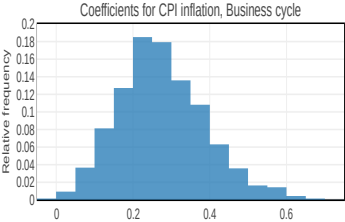
# The Role of Oil

## Unmodelled Components?



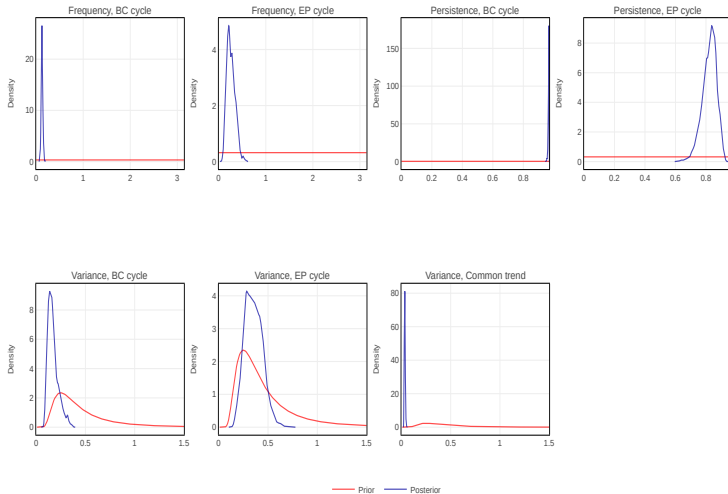
# Diagnostics

# Common Cycles Loadings



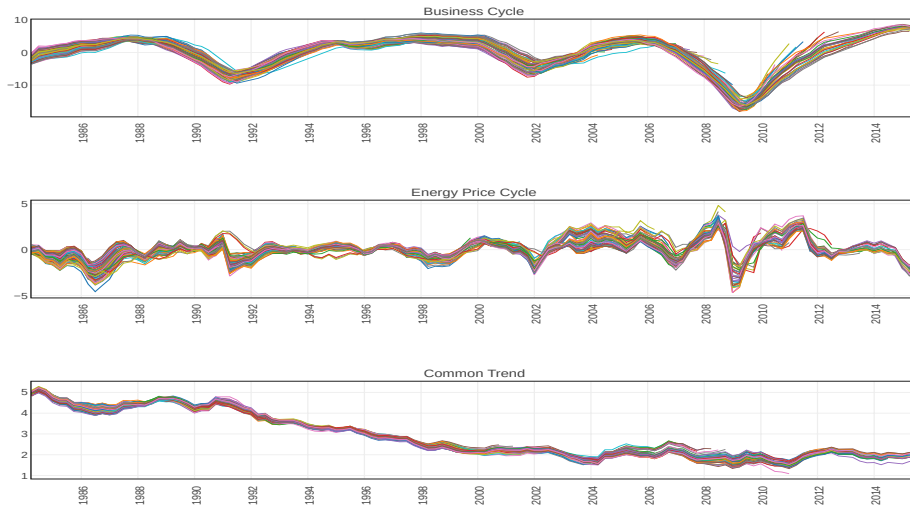
# Priors and Posteriors

## Variance of Shocks to the Components



# Model Forecasting Performances

# Out-of-Sample Cycle & Trend Revisions



# Out-of-Sample Forecast Evaluation

Root Mean Squared Forecast Error relative to the Random Walk with drift

Horizon	Variable	TC Model	BVAR	UC-SV	Horizon	Variable	TC Model	BVAR	UC-SV
h=1	Real GDP	1.04	<b>0.93</b>	x	h=4	Real GDP	1.11	<b>1.01</b>	x
	Employment	0.98	<b>0.76</b>	x		Employment	1.06	<b>0.82</b>	x
	Unemployment rate	0.85	<b>0.67</b>	x		Unemployment rate	0.86	<b>0.83</b>	x
	Oil price	<b>1.03</b>	1.08	x		Oil price	<b>1.03</b>	1.26	x
	CPI Inflation	0.94	<b>0.91</b>	1.00		CPI Inflation	<b>0.87</b>	1.13	0.97
	Core CPI Inflation	<b>1.01</b>	1.04	<b>1.01</b>		Core CPI Inflation	<b>0.95</b>	1.22	0.96
	UOM: Expected inflation	<b>0.98</b>	1.04	x		UOM: Expected inflation	<b>0.96</b>	1.14	x
h=2	SPF: Expected CPI	<b>0.95</b>	1.06	x		SPF: Expected CPI	<b>0.92</b>	1.31	x
	Real GDP	1.06	<b>0.93</b>	x	h=8	Real GDP	<b>1.17</b>	1.21	x
	Employment	1.00	<b>0.76</b>	x		Employment	1.13	<b>1.01</b>	x
	Unemployment rate	0.85	<b>0.71</b>	x		Unemployment rate	<b>0.85</b>	1.02	x
	Oil price	<b>1.04</b>	1.18	x		Oil price	<b>0.99</b>	1.36	x
	CPI Inflation	<b>0.90</b>	0.98	0.99		CPI Inflation	<b>0.81</b>	1.09	0.95
	Core CPI Inflation	<b>0.99</b>	1.15	<b>0.99</b>		Core CPI Inflation	<b>0.84</b>	1.30	0.91
	UOM: Expected inflation	<b>0.98</b>	1.09	x		UOM: Expected inflation	<b>0.92</b>	1.28	x
h=4	SPF: Expected CPI	<b>0.94</b>	1.18	x		SPF: Expected CPI	<b>0.88</b>	1.34	x



# Conclusions (I)

- Our trend-cycle model captures a number of commonly accepted economic laws and provides a **powerful new tool** for policy analysis.
- The model correctly captures inflation dynamics since the 1980s and identifies a stable and fairly steep **Phillips Curve**
- The Phillips Curve is **not** always the **dominant component**
- Large **oil price fluctuations** can **move consumers' expectations** away from the real-nominal relationship

## Conclusions (II)

- Explicit modelling of **trends & cycles** and **parsimonious** characterisation of the relations amongst macro variables
- Similar to VARs but **informed by Economic theory** – Phillips Curve, Okun's Law
- Encompasses **REH** but allows for **deviations** from **full information and perfect rationality**
- Can deal with **trending variables** and **multiple cycles**
- **No need of data transformation** generating spurious correlations
- ... nor of tight parametrisation as DSGE models.
- **Good forecasting model**, a **story telling device** and for **nowcasting**