Misspecified Forecasts and Myopia in an Estimated New Keynesian Model

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Expectations in Dynamic Macroeconomic Models

September 1, 2021

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Introduction

- Full-information Rational Expectations (FIRE)
  - Postulates that agents understand the true underlying model of the economy and appropriately take into account future payoffs and quantities
  - Is the workhorse of modern macro and has produced much discipline and important insights
  - Contrasts with ample evidence that agents often resort to simple autoregressive forecasting rules and extra-discount the future

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  - Contrasts with ample evidence that agents often resort to simple autoregressive forecasting rules and extra-discount the future
- This paper proposes a *combination* of misspecified autoregressive forecasts and myopia
  - Estimates their relative importance on macroeconomic fluctuations in a baseline New Keynesian model w/ habit in consumption and inflation indexation

Contributions and Key Results

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  - A combination of misspecified forecasts and myopia is preferred over other expectations alternatives, including RE
- Develops the full general equilibrium solution and estimates it on U.S. data w/ state-of-the-art likelihood-based Bayesian methods
  - Best fitting expectations formation process for both households and firms is characterized by high degrees of myopia and simple AR(1) forecasting rules
    - Delayed over-shooting of forecasters

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  - Best fitting expectations formation process for both households and firms is characterized by high degrees of myopia and simple AR(1) forecasting rules
    - Delayed over-shooting of forecasters
  - The estimated high degree of myopia - in the presence of misspecified forecasts - generates substantial internal persistence and amplification to exogenous shocks
    - Frictions, such as habit in consumption, are significantly less important

New Keynesian Pricing (partial equilibrium)

- Continuum of monopolistically competitive firms
- Calvo pricing: $\alpha \in (0, 1)$ fraction of firms cannot reset their price each period
- Homogeneous w.r.t. economic problems, shocks and beliefs
- Do not understand the true model of the economy
- Understand the process of the exogenous shocks

Log-linearized Optimal Price

$$\hat{p}_t^* = \widetilde{\mathbb{E}}_t \sum_{h=0}^{\infty} (\alpha\beta)^h \left(\hat{mc}_{t+h} + \alpha\beta\hat{\pi}_{t+h+1} + \hat{\mu}_{t+h} \right) \tag{1}$$

- $\hat{p}_t^* = log(P_t^*/P_t)$; $\hat{P}_t^*$ - optimal price; $\hat{P}_t$ - aggregate price
- $\hat{\pi}_t$ - inflation
- $\widetilde{\mathbb{E}}_t$ - generic expectation operator satisfying law of iterative expectations and standard probability rules
- $\hat{mc}_t$ - exogenous marginal cost: $\hat{mc}_t = \rho\hat{mc}_{t-1} + \varepsilon_t$, $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$
- $\hat{\mu}_t \sim N(0, \sigma_u^2)$ - i.i.d. cost-push shock

Myopia

- Gabaix (AER, 2020): $\widetilde{\mathbb{E}}_t \hat{\pi}_{t+h} = n^h \mathbb{E}_t \hat{\pi}_{t+h}$
  - $n \in (0, 1]$ – degree of myopic adjustment, $h \geq 1$ - horizon
  - $\mathbb{E}_t$ – RE operator
  - Under-reaction to new info (made available at the time of forecast) for short and long forecast horizons

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  - Under-reaction to new info (made available at the time of forecast) for short and long forecast horizons
- This paper:

$$\widetilde{\mathbb{E}}_t\hat{\pi}_{t+h} = w_f n^h \widetilde{\mathbb{E}}^{\star}_t\hat{\pi}_{t+h} \quad (2)$$

  - $\widetilde{\mathbb{E}}^{\star}_t\hat{\pi}_{t+h}$ – misspecified autoregressive forecast
  - $w_f \geq 1$ – upward reweighing factor
  - Can capture delayed over-shooting (Angeletos et al. (NBER Macro Annual, 2020))

Misspeficied Forecasting Rules

- Optimal pricing scheme:

$$\hat{p}_t^* = w_f \widetilde{\mathbb{E}}_t^\star \sum_{h=0}^{\infty} (\alpha\beta n)^h \left(\hat{mc}_{t+h} + \alpha\beta n \hat{\pi}_{t+h+1} + \hat{\mu}_{t+h} \right) \tag{3}$$

- Perceived law of motion (PLM) for $\hat{mc}_t$: $\hat{mc}_t = \rho \hat{mc}_{t-1} + \varepsilon_t$

$$\widetilde{\mathbb{E}}_t^\star \hat{mc}_{t+h} = \rho^h \hat{mc}_t$$

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- $\widetilde{\mathbb{E}}_t^\star \hat{\mu}_{t+h} = 0$

- Motivated by Adam (EJ, 2007), Fuster et. al. (JEP, 2010), Hommes and Zhu (JET, 2014), Hommes (JEL, 2019)

- AR(1) PLM for inflation: $\hat{\pi}_t = \delta + \gamma(\hat{\pi}_{t-1} - \delta) + \epsilon_t$, $\epsilon_t \sim WN$

$$\widetilde{\mathbb{E}}_t^\star \hat{\pi}_{t+h} = \delta(1 - \gamma^{h+1}) + \gamma^{h+1} \hat{\pi}_{t-1} \tag{4}$$

Stochastic Consistent Expectations Equilibrium (SCEE)

Let $\Theta = \{\alpha, \beta, \kappa, \rho\}$

- Actual law of motion (ALM) for inflation:

$$\hat{\pi}_t = c(\Theta, \gamma, n)\delta + a_0(\Theta, n)\hat{mc}_t + a_1(\Theta, \gamma, n)\hat{\pi}_{t-1} + \underbrace{\hat{u}_t}_{\text{linear fnc. } \hat{\mu}_t} \tag{5}$$

- (δ, γ): SCEE - Hommes and Zhu (JET, 2014)

Definition

The pair (δ, γ) with $\delta = \mathbb{E}\left(\hat{\pi}_t | ALM\right)$ and $\gamma = Corr(\hat{\pi}_t, \hat{\pi}_{t-1} | ALM)$ is a first-order SCEE.

- $\delta^* = 0$, γ^* - can be found numerically

Testable Implications

$$\underbrace{\hat{\pi}_{t+h} - \widetilde{\mathbb{E}}_t \hat{\pi}_{t+h}}_{FE_{t,t+h}} = K_h \underbrace{\left(\widetilde{\mathbb{E}}_t \hat{\pi}_{t+h} - \widetilde{\mathbb{E}}_{t-1} \hat{\pi}_{t+h} \right)}_{FR_{t,t+h}} + \bar{\zeta} \widetilde{\mathbb{E}}^{\star}_{t-1} \hat{\pi}_{t+h} + error_{t+h} \tag{6}$$

- $K_h = \frac{1 - w_f n^h}{w_f n^h}$ and $\bar{\zeta} = n(1 - w_f n^h)$

Testable Implications

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- $K_h = \frac{1 - w_f n^h}{w_f n^h}$ and $\bar{\zeta} = n(1 - w_f n^h)$
- Myopia & autoregressive forecast: $\widetilde{\mathbb{E}}^{\star}_{t-1} \hat{\pi}_{t+h} = (\gamma^*)^{h+1} \hat{\pi}_{t-2}$

$$FE_{t,t+h} = K_h FR_{t,t+h} + \zeta_{2,h} \hat{\pi}_{t-2} + error_{t+h} \tag{7}$$

Survey of Professional Forecasters Evidence

1. Focus on annual inflation forecast ($h = 3$) from 1968:Q4 - 2014:Q2

2. Regardless of $\widetilde{\mathbb{E}}^{\star}$:

   - $\mathbb{E}(FR_{t,t+h} error_t) \neq 0 \Rightarrow$ biased OLS estimate of K_h
   - Solution: similar to Coibion and Gorodnichenko (AER, 2015), use instruments (first and second lag of oil price change, and second lag of Fernald's TFP series)

3. Autoregressive forecast:

   - $\mathbb{E}(\hat{\pi}_{t-2} error_t) \neq 0 \Rightarrow$ biased OLS estimate of $\zeta_{2,h}$
   - Remedy: add $\hat{\pi}_{t-1}$ and $\hat{\pi}_{t-3}$ as regressors Details

$$FE_{t,t+h} = c_h + K_h FR_{t,t+h} + \sum_{i=1}^{3} \zeta_{i,3} \hat{\pi}_{t-i} + error_t \quad (8)$$

Survey of Professional Forecasters Evidence

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
$FR_{t,t+3}$	1.19**	1.14**	1.14***	1.91***	2.10**	1.40**
	(0.49)	(0.45)	(0.42)	(0.60)	(0.87)	(0.68)
$\hat{\pi}_{t-1}$		0.02	-0.00		-0.05	-0.06
		(0.05)	(0.07)		(0.07)	(0.13)
$\hat{\pi}_{t-2}$			0.1*			0.13*
			(0.05)			(0.07)
R^2	0.20	0.20	0.21	0.12	0.09	0.20
F-stat				14.07	9.24	9.54
Obs	172	172	172	172	172	172

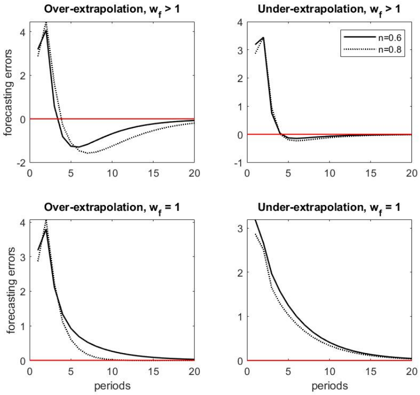
Newey-West (robust) standard errors in parentheses for OLS (IV)

***p<0.01, **p<0.05, *p<0.1

More details

Delayed Over-shooting

- $\mathbb{I}_t = \frac{\partial(\hat{\pi}_{t+k} - \widetilde{\mathbb{E}}_{t+k-1}\hat{\pi}_{t+k})}{\partial \varepsilon_t}$ (Angeletos et al. (NBER Macro Annual, 2020))
  - if $w_f = 1$ for all $n \in (0, 1]$, there will be delayed over-shooting only if $\gamma^* >> \rho$
  - if $w_f > 1$, there can be delayed over-shooting even if $\gamma^* < \rho$



Relation to Other Expectations Assumptions

- Full-information RE: forecast errors are accumulated noise orthogonal to any piece of information at the time of forecast
- Myopia and well-specified forecasting rules: forecast errors depend on revisions and $\hat{\pi}_{t-1}$ (Gabaix (AER, 2020))
- No myopia and misspecified forecasting rules: consistent with forecasting data iff there is sufficient over-extrapolation $\gamma^* >> \rho$

Full New Keynesian Model

Preston (IJCB, 2005), Milani (IJCB, 2005)

- Aggregate demand

$$\hat{\hat{x}}_t = (1-\beta+\beta\eta)\widetilde{\mathbb{E}}_t\hat{\hat{x}}_{t+1} + \widetilde{\mathbb{E}}_t\sum_{h=0}^{\infty}\beta^h\left(\beta(1-\beta)(1-\eta)\hat{\hat{x}}_{t+h+2} - \frac{1-\beta\eta}{\sigma}(\hat{R}_{t+h} - \hat{\pi}_{t+h+1} - \hat{e}_{t+h})\right) \quad (9)$$

  - $\hat{\hat{x}}_t = \hat{x}_t - \eta\hat{x}_{t-1}$; $\hat{x}_t$ - output gap
  - demand shock: $\hat{e}_t = \rho_e\hat{e}_{t-1} + \sigma_e\varepsilon_t^e$, $\varepsilon_t^e \sim N(0,1)$

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- Aggregate Supply after myopic adjustment

$$\hat{\hat{\pi}}_t = \kappa\left(\omega\hat{x}_t + \frac{\sigma}{1-\beta\eta}\hat{\hat{x}}_t\right) + \widetilde{\mathbb{E}}_t\sum_{h=1}^{\infty}(\alpha\beta)^{h-1}\left(\kappa\beta(\omega\alpha\hat{x}_{t+h} + \frac{\sigma\eta(\alpha-\eta)}{1-\beta\eta}\hat{\hat{x}}_{t+h}) + \beta(1-\alpha)\hat{\hat{\pi}}_{t+h} + \hat{u}_{t+h-} \right. \tag{10}$$

  - $\hat{\hat{\pi}}_t = \hat{\pi}_t - \rho_\pi\hat{\pi}_{t-1}$
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Full New Keynesian Model

Preston (IJCB, 2005), Milani (IJCB, 2005)

- Aggregate demand

$$\hat{\tilde{x}}_t = (1-\beta+\beta\eta)\widetilde{\mathbb{E}}_t\hat{\tilde{x}}_{t+1} + \widetilde{\mathbb{E}}_t \sum_{h=0}^{\infty} \beta^h \left(\beta(1-\beta)(1-\eta)\hat{\tilde{x}}_{t+h+2} - \frac{1-\beta\eta}{\sigma}(\hat{R}_{t+h} - \hat{\pi}_{t+h+1} - \hat{e}_{t+h}) \right) \tag{9}$$

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  - supply shock: $\hat{u}_t = \rho_u\hat{u}_{t-1} + \sigma_u\varepsilon_t^u$, $\varepsilon_t^u \sim N(0,1)$
- Monetary Policy: $\hat{R}_t = \rho_R\hat{R}_{t-1} + (1-\rho_R)\left(\phi_x\hat{x}_t + \phi_\pi\hat{\pi}_t\right) + \sigma_v\varepsilon_t^v$, $\varepsilon_t^v \sim N(0,1)$

Learning Misspecified Forecasting Rules

- Agents learn to use **AR(1)** or VAR(1) about the output gap, inflation and nominal interest rates nested in Z_t

$$Z_t = \boldsymbol{\delta}_{t-1} + \gamma_{t-1}(Z_{t-1} - \boldsymbol{\delta}_{t-1}) + \epsilon_t,\ \epsilon_t \sim WN \tag{11}$$

  - $\boldsymbol{\delta}_{t-1}$ - mean of Z_{t-1} series
  - γ_{t-1} - first-order correlation between Z_{t-1} and Z_{t-2}

$$\widetilde{\mathbb{E}}_t^{\star} Z_{t+h} = \boldsymbol{\delta}_{t-1} + \gamma_{t-1}^{h+1}(Z_{t-1} - \boldsymbol{\delta}_{t-1}) \tag{12}$$

  - $\boldsymbol{\delta}_t$ and γ_t updated according to Sample Autocorrelation learning (Hommes and Sorger (MD, 1998)), with constant gain learning, $\bar{\iota}$

Posterior Distribution

Parameters	RE			$n \in (0,1)$			$n = 1$		
	mean	5%	95%	mean	5%	95%	mean	5%	95%
α	0.496	0.171	0.826	0.576	0.220	0.866	0.935	0.775	0.994
n	-	-	-	0.424	0.230	0.612	-	-	-
η	0.926	0.877	0.982	0.011	0.002	0.025	0.001	0.000	0.004
ρ_π	0.922	0.866	0.987	0.881	0.773	0.976	0.022	0.001	0.064
ρ_e	0.623	0.504	0.735	0.855	0.763	0.927	0.964	0.934	0.990
ρ_u	0.022	0.000	0.050	0.027	0.002	0.079	0.851	0.784	0.913
σ_e	6.144	2.770	10.000	1.185	1.050	1.317	0.185	0.080	0.306
σ_u	0.266	0.242	0.288	0.179	0.067	0.307	0.057	0.034	0.094
σ_v	0.209	0.192	0.226	0.208	0.192	0.226	0.208	0.192	0.226
$\bar{\iota}$	-	-	-	0.050	0.026	0.084	0.005	0.002	0.011
MHM	-276.54			-267.75*			-303.18		
Bayes factor	(1)			$(e^{8.79})$			$(e^{-26.64})$		

Prior, AR(1) Forecast Evolution, VAR(1) Forecast Evolution

IRF: Misspecified Forecasts & Myopia versus RE

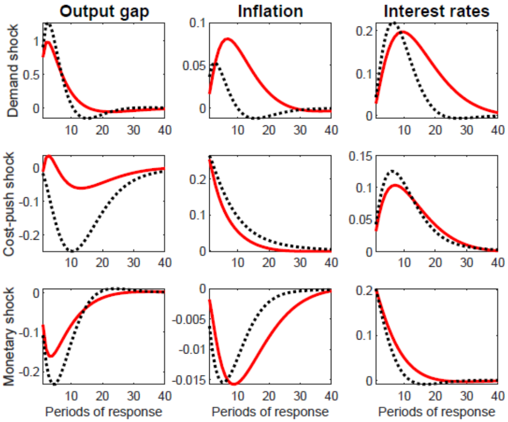
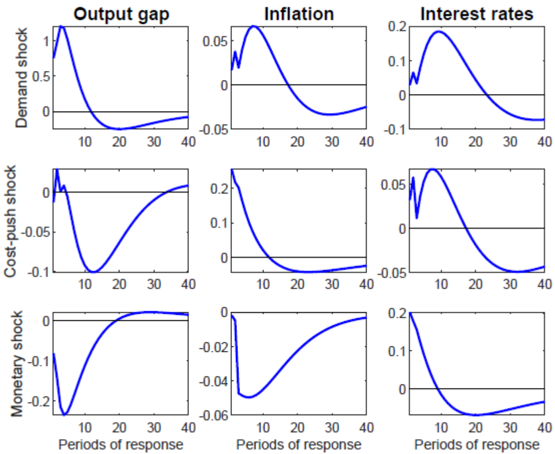


Figure: Red curve: Misspecified Forecast & Myopia; Dashed curve: RE.

3-D IRF, Myopia vs. No Myopia

IRF of 1-period ahead Forecast Errors



IRF of Annual Forecast Errors, 3D-IRF of 1-period ahead Forecast Errors

Concluding Remarks

- Two distinct estimation approaches lead to the same result that misspecified autoregressive forecasts and myopia are preferred over the RE alternatives, among others
- The best fitting expectations formation process for both households and firms is characterized by high degrees of myopia and simple AR(1) forecasts
  - Delayed forecasters' over-shooting
- The estimated high degree of myopia - in the presence of misspecified forecasts - generates substantial internal persistence and amplification to exogenous shocks
  - Frictions, that are necessary under RE, are significantly less important

Aggregate Demand and Supply after Myopic Adjustment

$$\hat{\tilde{x}}_t = n\frac{(1-\beta n)(1-\beta+\beta\eta)}{1-\beta}\widetilde{\mathbb{E}}_t\hat{\tilde{x}}_{t+1} + \widetilde{\mathbb{E}}_t\sum_{h=0}^{\infty}(\beta n)^h\left(\beta(1-\beta n)(1-\eta)\hat{\tilde{x}}_{t+h+2} - \frac{1-\beta\eta}{\widetilde{\sigma}}(\hat{R}_{t+h}-\hat{\pi}_{t+h+1}-\hat{e}_{t+h})\right) \tag{13}$$

$$\hat{\tilde{\pi}}_t = \widetilde{\kappa}\left(\widetilde{\omega}\hat{x}_t + \frac{\widetilde{\sigma}}{1-\beta\eta}\hat{\tilde{x}}_t\right) + \widetilde{\mathbb{E}}_t\sum_{h=1}^{\infty}(\alpha\beta n)^{h-1}\left(\widetilde{\kappa}\beta(\widetilde{\omega}\alpha\hat{x}_{t+h} + \frac{\widetilde{\sigma}\eta(\alpha-\eta)}{1-\beta\eta}\hat{\tilde{x}}_{t+h}) + \beta(1-\alpha n)\hat{\tilde{\pi}}_{t+h} + \hat{u}_{t+h-1}\right) \tag{14}$$

- $\widetilde{\sigma} = \sigma\frac{1-\beta n}{1-\beta}$
- $\widetilde{\kappa} = \kappa\frac{\sigma(1-\alpha n)}{\widetilde{\sigma}(1-\alpha)}$
- $\widetilde{\omega} = \frac{\sigma(1-\alpha n)}{\widetilde{\sigma}(1-\alpha)}$

Back to Full New Keynesian Model

AR(1) Forecast Evolution

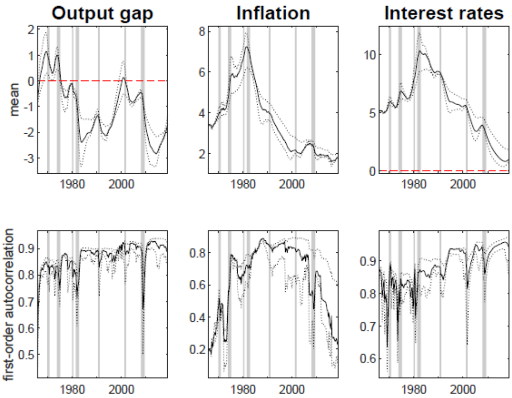


Figure: The black and dotted curves plot implied beliefs for structural parameters set at their estimated posterior mean and 90% highest posterior density, respectively. Grey areas indicate recessionary periods as reported by NBER.

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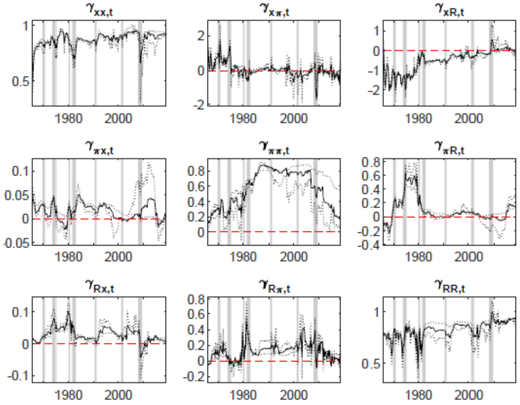
VAR(1) Forecast Evolution



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$\hat{\pi}_{t-1}$		0.02	-0.00		-0.05	-0.06
		(0.05)	(0.07)		(0.07)	(0.13)
$\hat{\pi}_{t-2}$			0.1*			0.13*
			(0.05)			(0.07)
$\hat{\pi}_{t-3}$			-0.081			-0.051
			(0.055)			(0.082)
Const	0.002	-0.074	-0.072	0.004	0.190	-0.106
	(0.144)	(0.174)	(0.186)	(0.084)	(0.263)	(0.177)
R^2	0.20	0.20	0.21	0.12	0.09	0.20
F-stat				14.07	9.24	9.54
Obs	172	172	172	172	172	172

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

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Prior Distribution

Parameters		pdf	mean	standard deviation
Calvo parameter	α	$\mathcal{B}$	0.5	0.2
Degree of myopia	n	$\mathcal{U}$	0.5	$1/\sqrt{12}$
Habit in consumption	η	$\mathcal{U}$	0.5	$1/\sqrt{12}$
Inflation indexation	ρ_π	$\mathcal{U}$	0.5	$1/\sqrt{12}$
Autocorr. e	ρ_e	$\mathcal{U}$	0.5	$1/\sqrt{12}$
Autocorr. u	ρ_u	$\mathcal{U}$	0.5	$1/\sqrt{12}$
Std. ε^e	σ_e	$\mathcal{IG}$	0.1	2
Std. ε^u	σ_u	$\mathcal{IG}$	0.1	2
Std. ε^v	σ_v	$\mathcal{IG}$	0.1	2
Gain parameter	$\bar{\iota}$	$\mathcal{G}$	0.035	0.015

Table: **Priors**

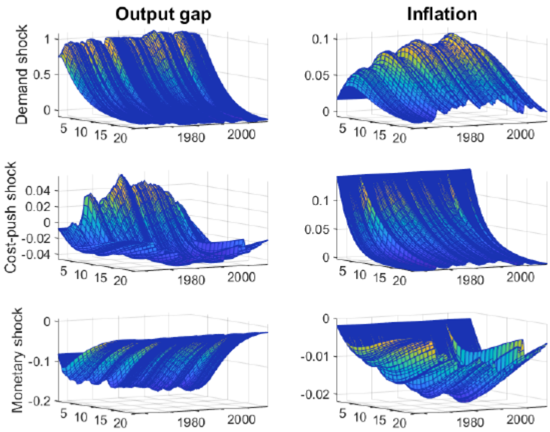
Back to Bayesian Estimation

Forecast Recursive Updating

$$\begin{aligned}
\boldsymbol{\delta}_t &= \boldsymbol{\delta}_{t-1} + \bar{\iota}(Z_t - \boldsymbol{\delta}_{t-1}) \\
\gamma_t &= \gamma_{t-1} + \bar{\iota}\left((Z_t - \boldsymbol{\delta}_{t-1})(Z_{t-1} - \boldsymbol{\delta}_{t-1})' - \gamma_{t-1}(Z_t - \boldsymbol{\delta}_{t-1})(Z_t - \boldsymbol{\delta}_{t-1})'\right)\boldsymbol{\eta}_t^{-1} \\
\boldsymbol{\eta}_t &= \boldsymbol{\eta}_{t-1} + \bar{\iota}\left((Z_t - \boldsymbol{\delta}_{t-1})(Z_t - \boldsymbol{\delta}_{t-1})' - \boldsymbol{\eta}_{t-1}\right)
\end{aligned} \tag{15}$$

$\boldsymbol{\eta}_t$ is the second moment matrix, and ι is the gain parameter Back to main

3D-IRF: $n \in (0,1)$



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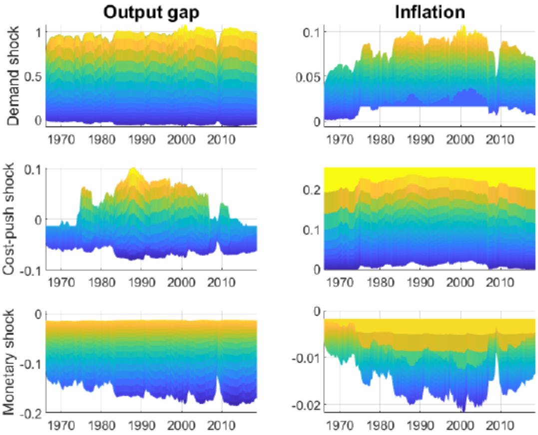
IRF Over Time: $n \in (0, 1)$



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Testable Implications

$$
\begin{aligned}
v_{t,t+3} &= \hat{\pi}_{t+3} - \widetilde{\mathbb{E}}_t^{\star}\hat{\pi}_{t+3} \\
&= a_0 \hat{mc}_{t+3} + a_1 \hat{\pi}_{t+2} - (\gamma^*)^5 \hat{\pi}_{t-1} \\
&= a_0 \sum_{i=0}^{5} \rho^{5-i} a_1^i \hat{mc}_{t-2} + a_1^5 \hat{\pi}_{t-3} - (\gamma^*)^5 \hat{\pi}_{t-1} + f(\varepsilon_{t-1}, \dots, \varepsilon_{t+3}) \\
&= \frac{1}{\rho} \sum_{i=0}^{5} \rho^{5-i} a_1^i (\hat{\pi}_{t-1} - a_1 \hat{\pi}_{t-2}) + a_1^5 \hat{\pi}_{t-3} - (\gamma^*)^5 \hat{\pi}_{t-1} + f(\varepsilon_{t-1}, \dots, \varepsilon_{t+3}) \\
&= \mathcal{F}(\hat{\pi}_{t-3}, \hat{\pi}_{t-2}, \hat{\pi}_{t-1}, \varepsilon_{t-1}, \dots, \varepsilon_{t+3})
\end{aligned}
$$

- Add $\hat{\pi}_{t-1}$ and $\hat{\pi}_{t-3}$ as regressors
- Left with $\mathbb{E}(v_{t,t+3}\hat{\pi}_{t-2}) = -\frac{a_1}{\rho} \sum_{i=0}^{5} \rho^{5-i} a_1^i \mathbb{E}(\hat{\pi}_{t-2}^2) \leq 0$
- The true estimate of $\zeta_{2,3}$ after adding $\hat{\pi}_{t-1}$ and $\hat{\pi}_{t-3}$ as regressors will be even larger than the OLS estimator

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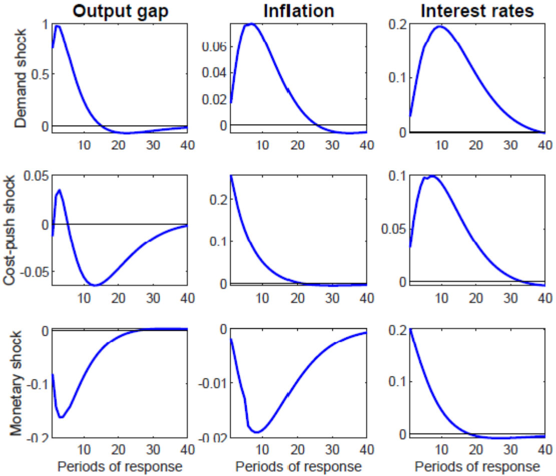
IRF of Annual Forecast Errors



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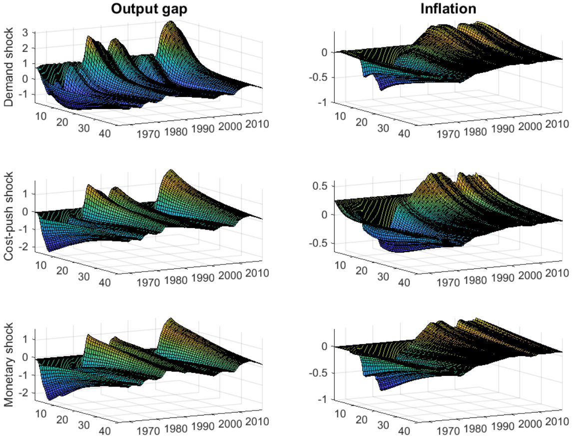
3D-IRF of 1-period ahead Forecast Errors



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Average IRF: Myopia vs No Myopia

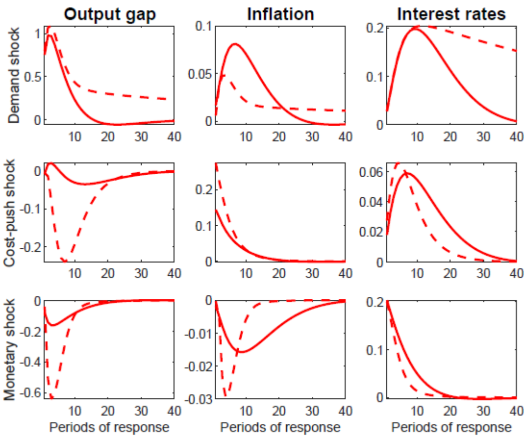

Figure: Red curve: Misspecified Forecast & Myopia; Dashed curve: Misspecified Forecasts & no Myopia.

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