Rigidity of Expectations: Additional Evidence from Density Forecasts of Professionals and Households

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Outline

Motivation

- there are various theories on "irrational expectation"
- different theories can be tested using survey data in a comparable manner (Coibion and Gorodnichenko (2012))
- a good theory needs to be (relatively) consistent in predictions across different moments
- higher moments, i.e. uncertainty, brings about one more restriction
- survey also contains information about data generating process itself

What this paper does

1. time series and cross-sectional pattern of uncertainty from **density** forecasts of the inflation
2. additional reduced-form tests of the full-information rationality null using the uncertainty
3. extend Coibion and Gorodnichenko (2012) in two ways
   - cross-moment estimation for each one of the particular theories on expectation
   - allowing for stochastic volatility of inflation process

Literature

- empirical tests on expectation formation
  - Mankiw et al. (2003), Carroll (2003), Branch (2004), Malmendier and Nagel (2015), Das et al. (2017), Coibion and Gorodnichenko (2012), Fuhrer (2018)
- density and probabilistic questions in expectation surveys
  - Manski (2004), Delavande et al. (2011), Manski (2018)
  - Bertrand and Mullainathan (2001), Van der Klaauw et al. (2008), Delavande (2014)
- different measures of uncertainty
  - Bachmann et al. (2013), Jurado et al. (2015), Binder (2017), Bloom (2009)

A generic framework

h-period ahead density forecast by agent i at time t based on information set $I_{i,t}$

$$f_{i,t+h|t} \equiv f_{i,t}(y_{t+h}|I_{i,t})$$

- theories of expectation differ in $I_{i,t}$
  - rational expectation (FIRE): $I_{i,t} = y_{i,t}$
  - sticky expectation (SE): $I_{i,t} = y_{t-\tau}$, τ being the most recent update date
  - noisy information (NI): $I_{i,t} = s_{i,t}(y_t)$, where $s_{i,t}$ is a vector of noisy signal(s)
- the process of variable determines the mapping from $I_{i,t}$ to $f_{i,t+h|t}$

Definition and notation

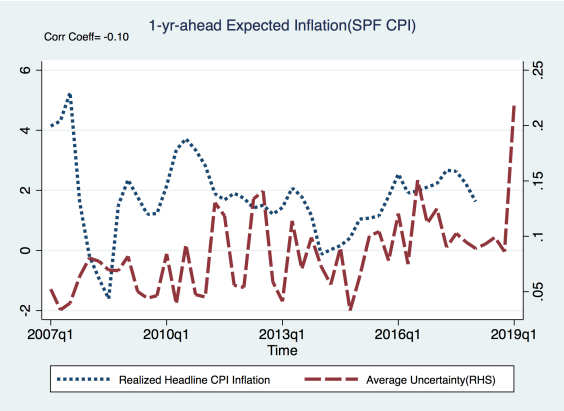
Individual moments	Population moments
Mean forecast: $y_{i,t+h\|t}$	Average forecast: $\bar{y}_{t+h\|t}$
Forecast error: $FE_{i,t+h\|t}$	Average forecast error: $\overline{FE}_{t+h\|t}$
Uncertainty: $Var_{i,t+h\|t}$	**Average uncertainty**: $\overline{Var}_{t+h\|t}$
	Disagreement: $\overline{Disg}_{t+h\|t}$

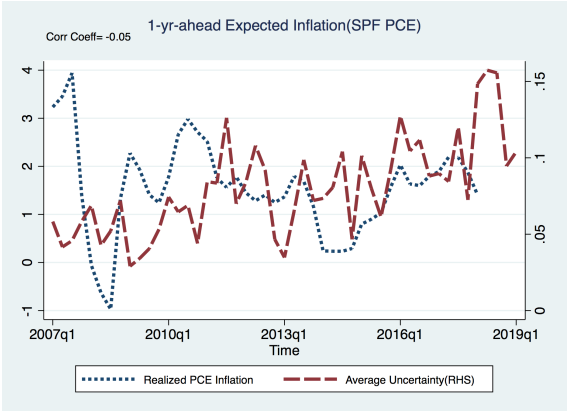
Data

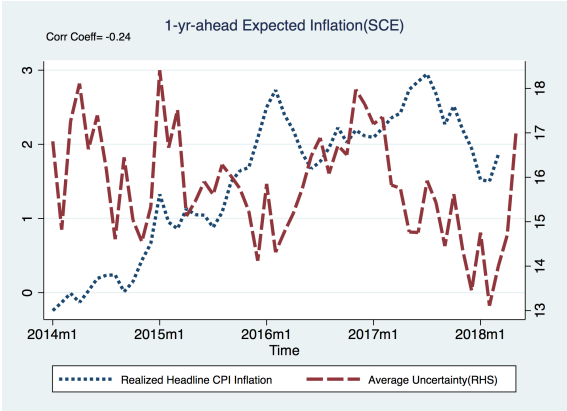
	SCE	SPF
Time period	2013M6-2018M6	2007Q1-2018Q4
Frequency	Monthly	Quarterly
Sample Size	1,300	30-50
Aggregate Var in Density	1-yr-ahead inflation	1-yr and 3-yr core CPI and core PCE
Pannel Structure	stay up to 12 months	average stay for 5 years
Demographic Info	Education, Income, Age	Industry

- density estimation following (Engelberg et al. (2009))
- exclude top and bottom 5% values for forecast errors and uncertainty

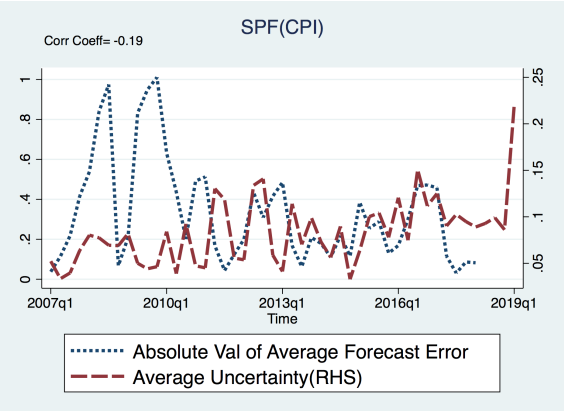
Basic patterns: uncertainty and realized inflation

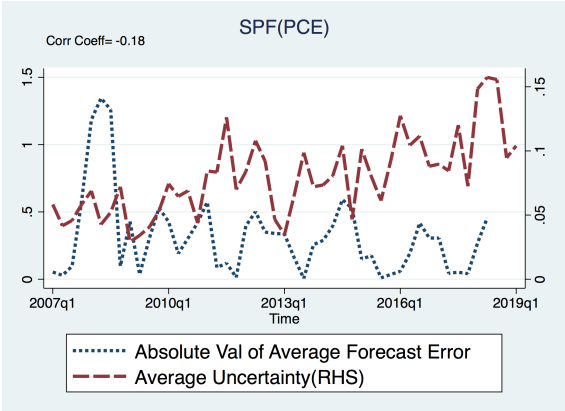


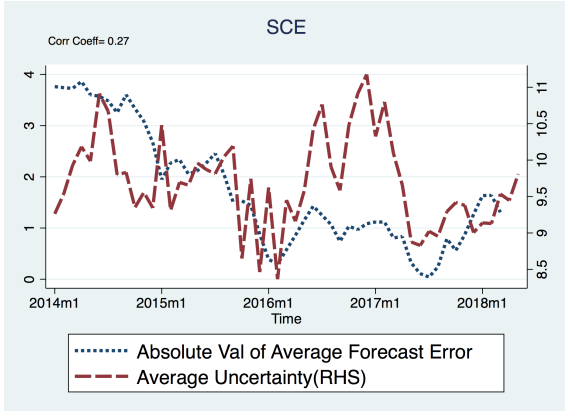




Basic patterns: uncertainty and the size of forecast errors

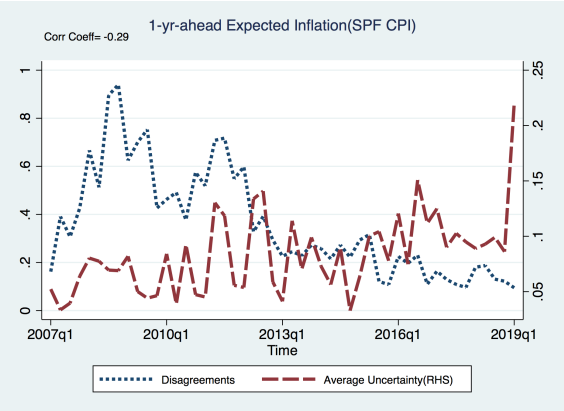


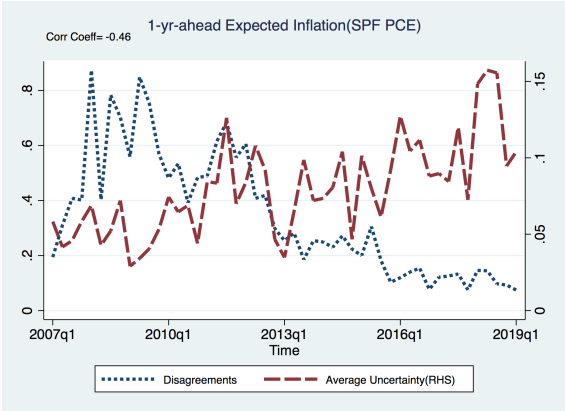


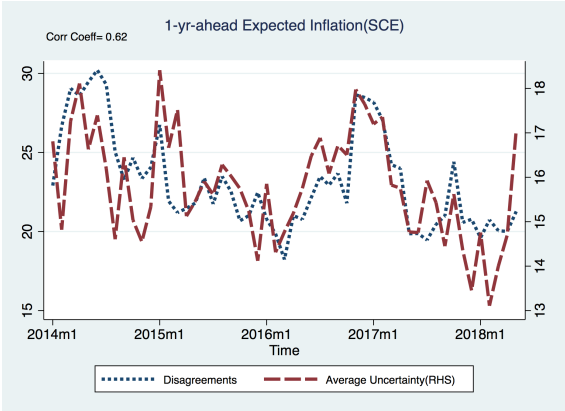


- no evidence for positive correlation betwen high ex ante uncertainty and ex post forecast errors.

Basic patterns: uncertainty and disagreement







- uncertainty are not the same as disagreement for professionals

Basic patterns: summary

- uncertainty varies across time
- uncertainty contains different information from widely proxies such as disagreement and forecast error

AR(1) model of inflation

- **Inflation process**

$$y_t = \rho y_{t-1} + \omega_t$$
$$\omega_t \sim N(0, \sigma_\omega^2)$$

- **Uncertainty**
  - FIRE: time-invariant

$$\overline{Var}^*_{t+h|t} = \sum_{s=1}^{h} \rho^{2s} \sigma_\omega^2$$

  - SE: time-invariant

$$\overline{Var}^{se}_{t+h|t} = \sum_{\tau=0}^{+\infty} \lambda(1-\lambda)^\tau \overline{Var}^*_{t+h|t-\tau}$$

  - NI: time-variant but quantitatively tiny due to highly efficient Kalman gain

$$\overline{Var}^{ni}_{t+h|t} = \rho^{2h} \overline{Var}^{ni}_{t|t} + \overline{Var}^*_{t+h|t}$$

Stocastic volatility (UCSV) inflation process (Stock and Watson (2007))

- **Inflation process**

$$
\begin{aligned}
y_t &= \theta_t + \eta_t, \quad \text{where } \eta_t = \sigma_{\eta,t}\xi_{\eta,t} \\
\theta_t &= \theta_{t-1} + \epsilon_t, \quad \text{where } \epsilon_t = \sigma_{\epsilon,t}\xi_{\epsilon,t} \\
\log \sigma^2_{\eta,t} &= \log \sigma^2_{\eta,t-1} + \mu_{\eta,t} \\
\log \sigma^2_{\epsilon,t} &= \log \sigma^2_{\epsilon,t-1} + \mu_{\epsilon,t}
\end{aligned}
$$

$$
\begin{aligned}
\xi_t &= [\xi_{\eta,t}, \xi_{\epsilon,t}] \sim N(0, I_2) \\
\mu_t &= [\mu_{\eta,t}, \mu_{\epsilon,t}]' \sim N(0, \gamma I_2)
\end{aligned}
$$

UCSV inflation process

- **Uncertainty**
  - FIRE: time-varying

$$\overline{Var}^{*}_{t+h|t} = \sum_{k=1}^{h} exp^{-0.5k\gamma_\eta}\sigma^2_{\eta,t} + exp^{-0.5h\gamma_\epsilon}\sigma^2_{\epsilon,t}$$

  - SE: time-varying

$$\overline{Var}^{se}_{t+h|t} = \sum_{\tau=0}^{\infty}(1-\lambda)^\tau \lambda \overline{Var}^{*}_{t+h|t-\tau}$$

  - NI (1-step-ahead): time-varying

$$\overline{Var}^{\theta}_{t|t-1} = \overline{Var}^{\theta}_{t-1|t-1} + Var^{*}_{t|t-1}(y_t)$$

Simulated method of moment estimation

$$\widehat{\Omega} = \underset{\{\Omega \in \Gamma\}}{argmin}(M_{\text{data}} - F^o(\Omega, Y))W(M_{\text{data}} - F^o(\Omega, Y))'$$

- Ω: parameters of the particular $o \in \{fire, se, ni\} \times \{ar, sv\}$
- Γ: constraints for the parameter.
- M_{data}: data moments
- F: simulated model moments according to a particular theory o, a function of parameters Ω as well as the Y, the real-time data (including history) up till each point of the time t.
  - unconditional moments, not specific to time
  - moments selected from average forecast, variance and autocovariance of forecasts, average diagreement, variance and autovariance of disagreement, average uncertainty, etc.
- W: weight matrix, identity matrix for now

Estimation procedure and algorithm

1. for each theory of expectation formation and the inflation process, start with an initial value for the parameter(s) of interest
2. simulate individual forecasts for a large enough ($N = 200$) number of forecasters
3. compute the average forecast errors, disagreement and average uncertainty across all agents
4. compute the time-series moments of the average forecast, disagreement, and uncertainty
5. compute the difference between the simulated moments and the data moments
6. keep searching the parameter value until reaching below a threshold of the loss

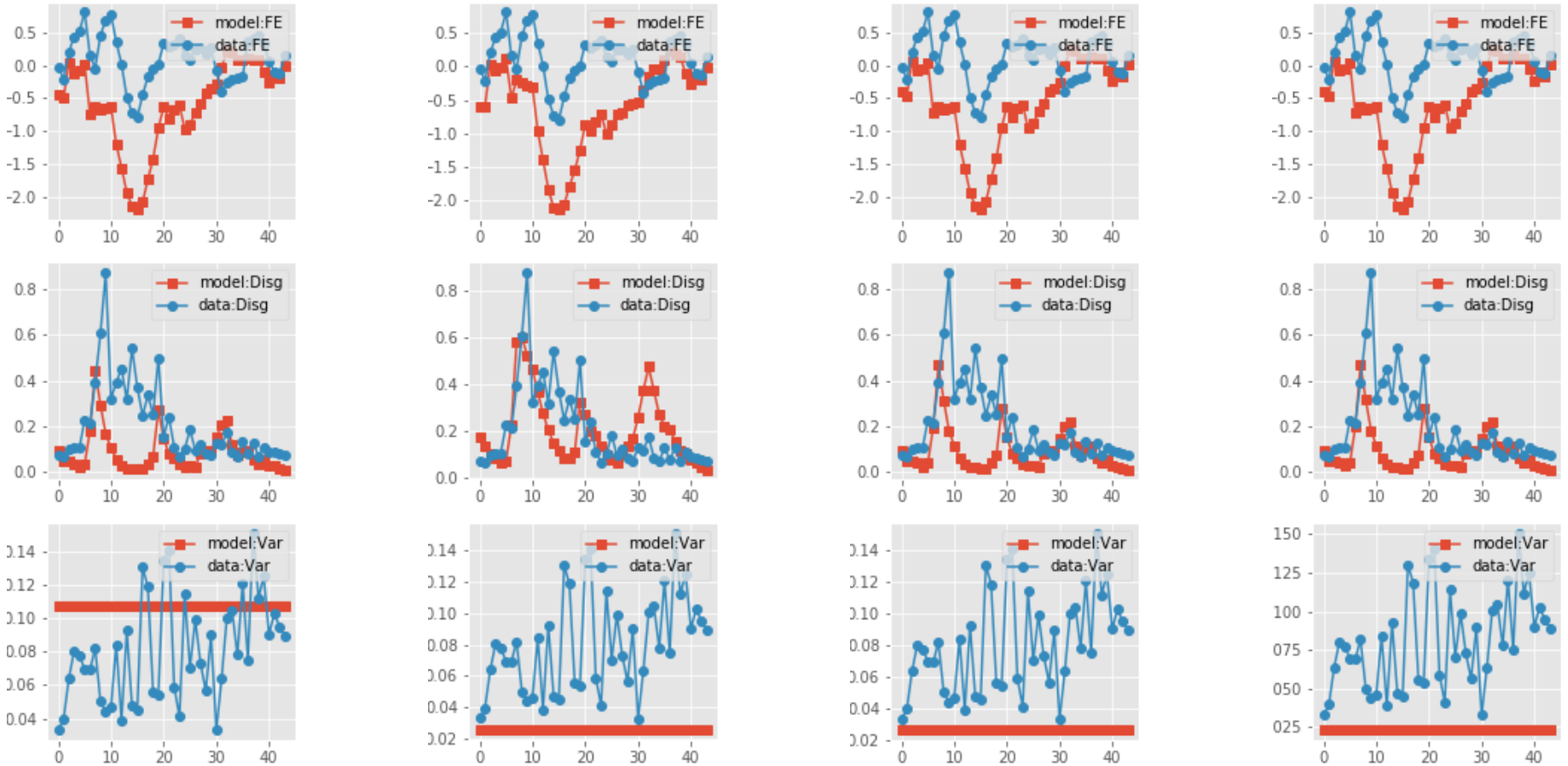
Two-step and joint estimation

1. two-step estimation: separately estimate inflation process parameters and then parameters of the inflation process
   - pros: computationally lighter
   - cons: potential misspecification. does not utilize the expectation data to understand inflation process per se.
2. joint estimation: targeting both moments of realized inflation series and moments of forecasts to simultaneously estimate both the inflation process and the parameter of expectation formation
   - pros: additional information gain from expectations data about inflation process itself
   - cons: more computation burden

Outline

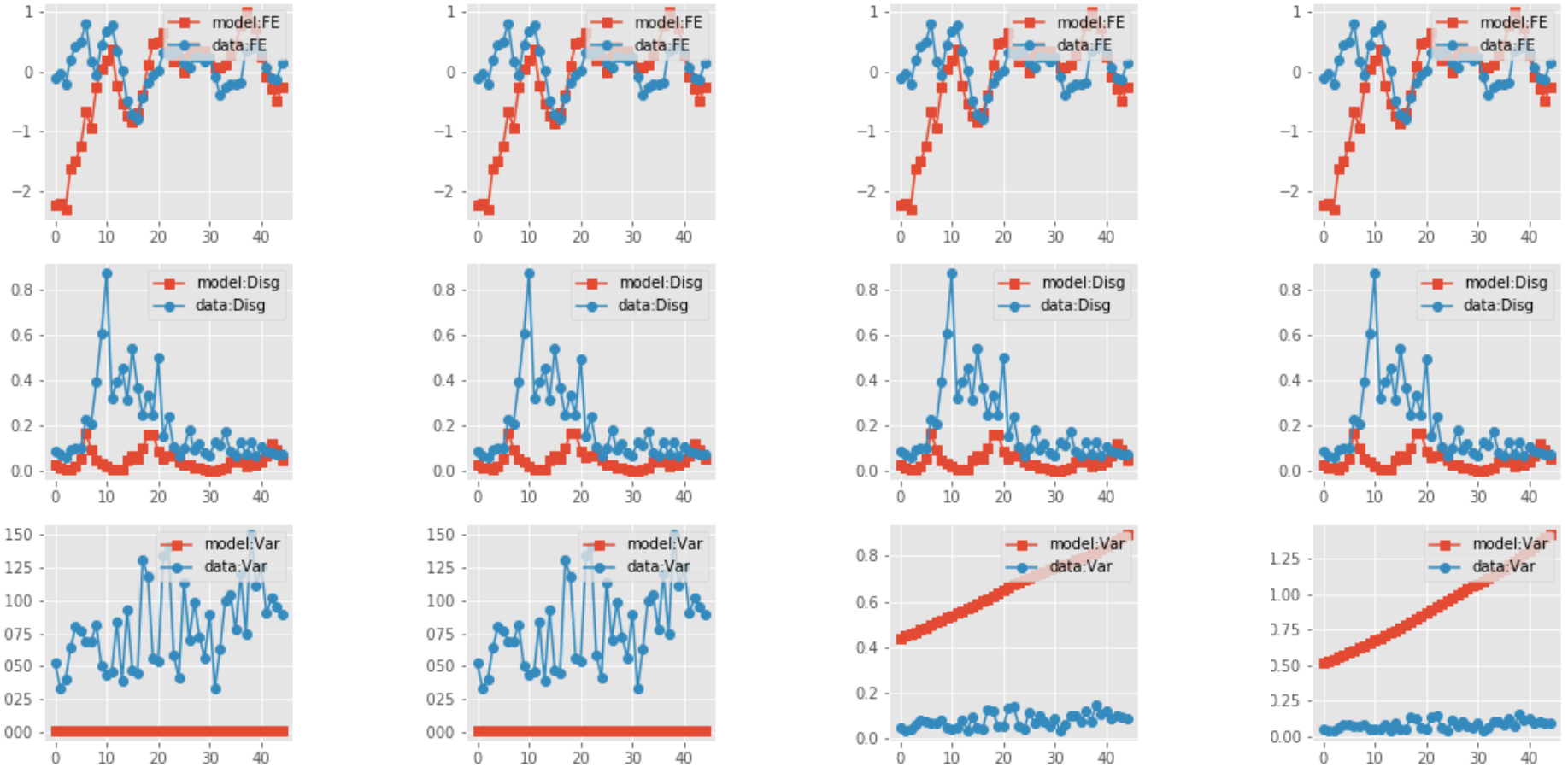
Professionals and SEAR

(a) FE (b) Disg (c) FE/Disg (d) FE/Disg/Var



Professionals and SEAR: joint estimation

(a) FE (b) Disg (c) FE/Disg (d) FE/Disg/Var



Households and SEAR

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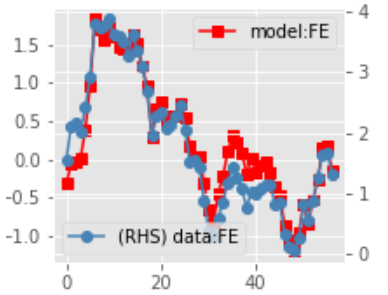
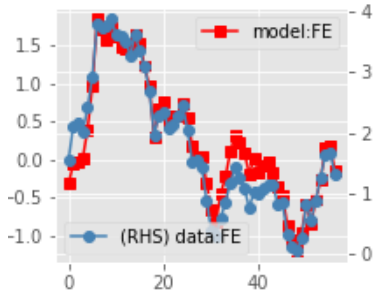
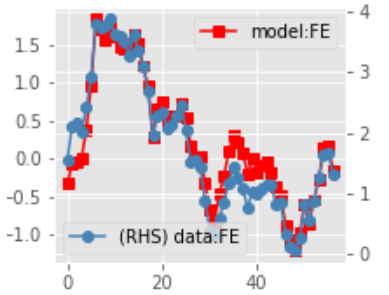
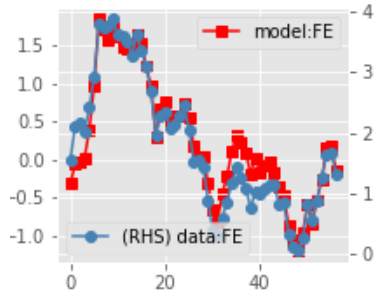
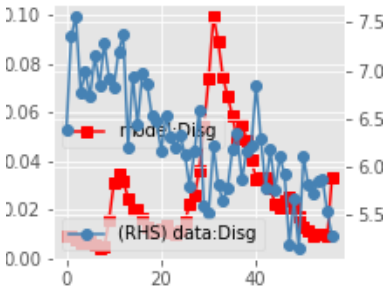
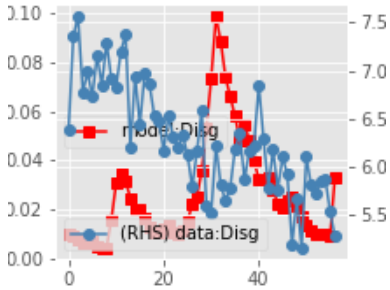


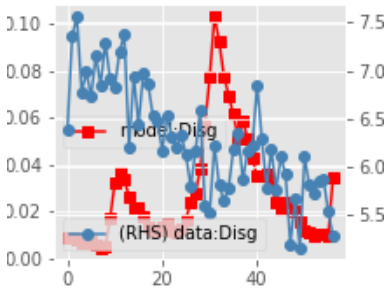


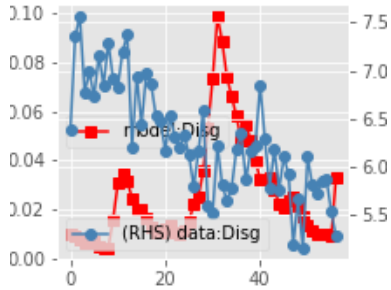


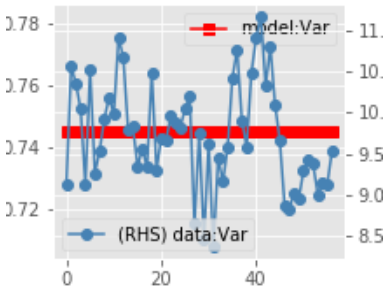


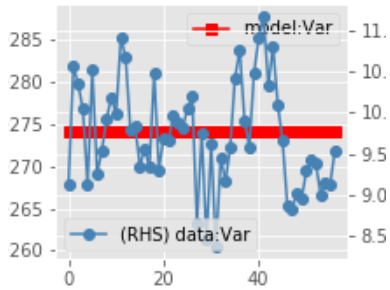


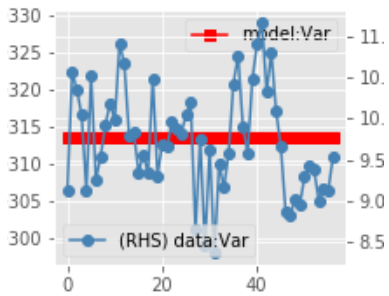


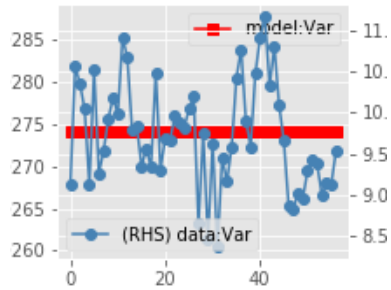






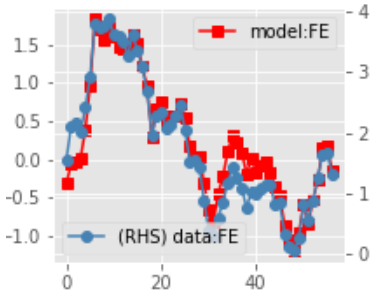


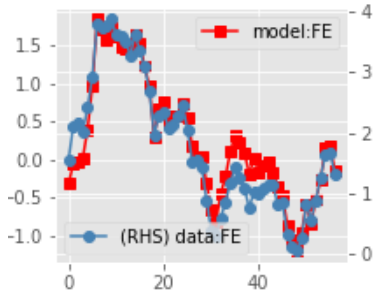


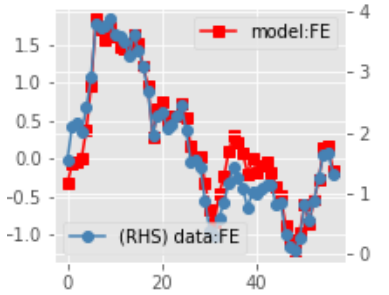


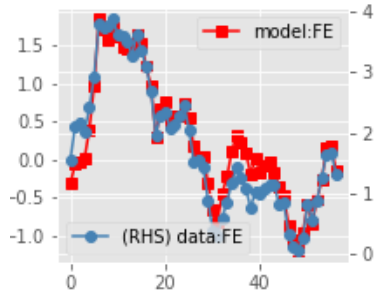
Households and SEAR: joint estimates

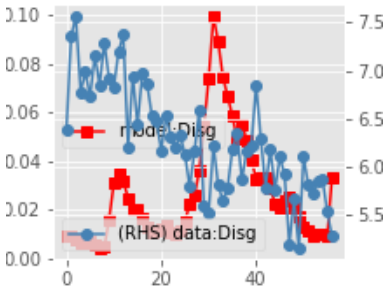
(a) FE (b) Disg (c) FE/Disg (d) FE/Disg/Var

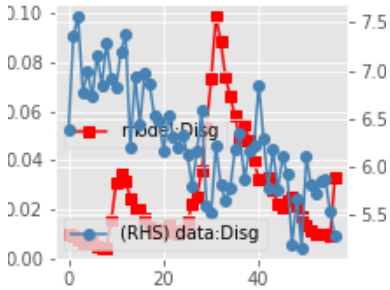


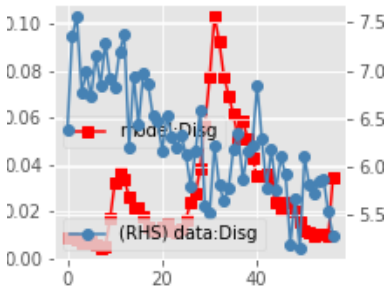


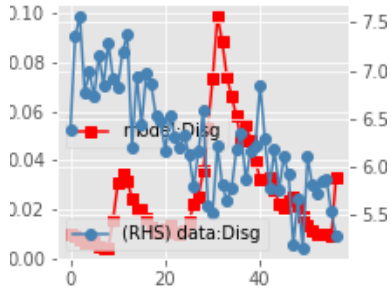


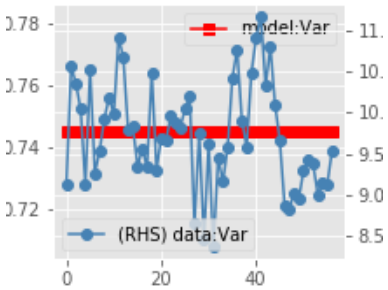


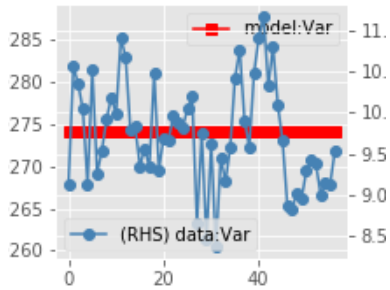


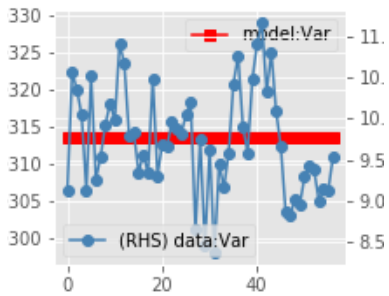


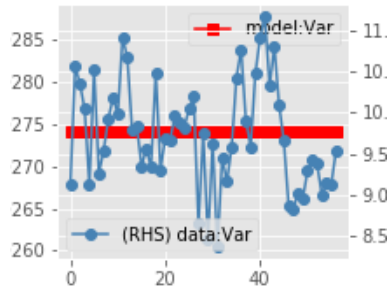












SE parameter estimate

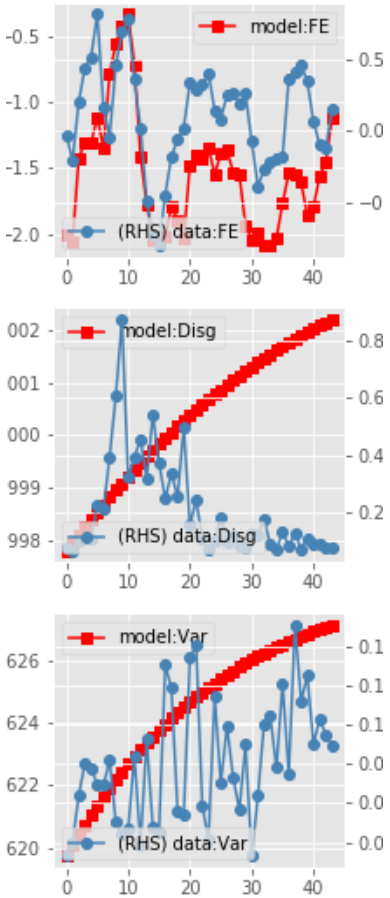
Table: SMM Estimates of Parameters of SE

0	1	2	3	SE: $\hat{\lambda}_{SPF}(Q)$	SE: $\hat{\lambda}_{SPF}(Q)$	SE
FEVar	FEATV			0.47	0.36	1
FEVar	DisgATV	DisgVar		0.27	0.38	1
FEVar	FEATV	DisgVar	DisgATV	0.47	0.36	1
FEVar	FEATV	DisgVar	DisgATV	0.47	0.36	1

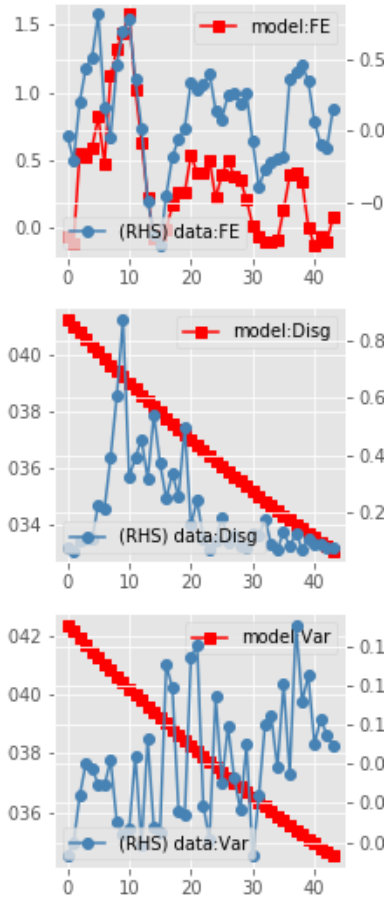
- λ: update rate in SE

Professionals and NIAR

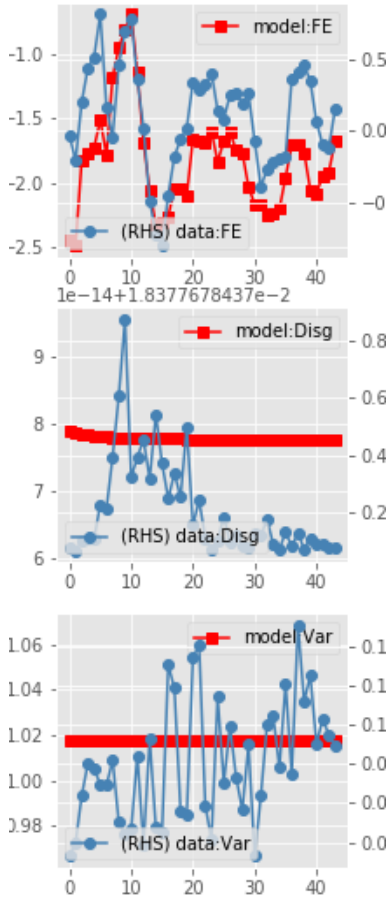
(a) FE



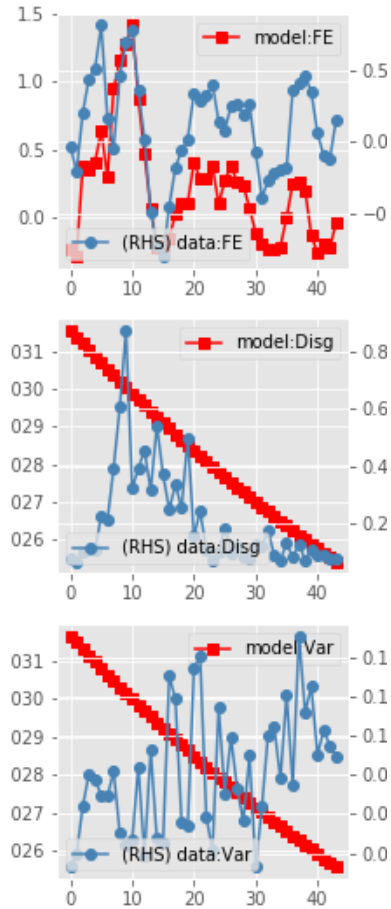
(b) Disg



(c) FE/Disg



(d) FE/Disg/Var



Professionals and NIAR: joint estimates

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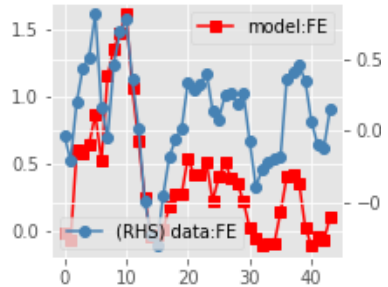
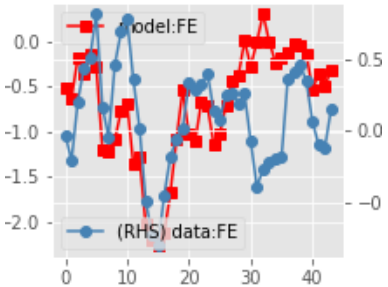
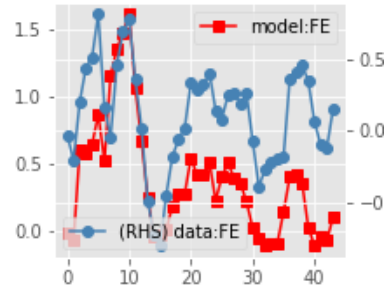
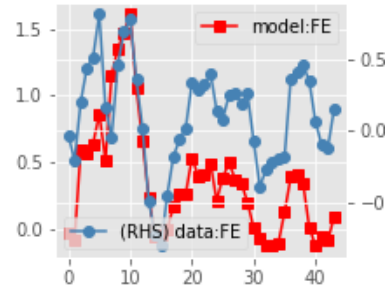
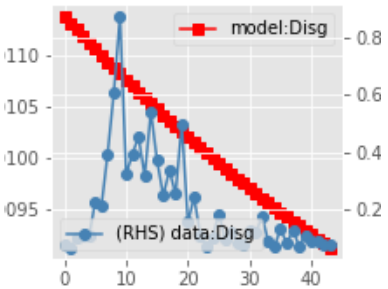
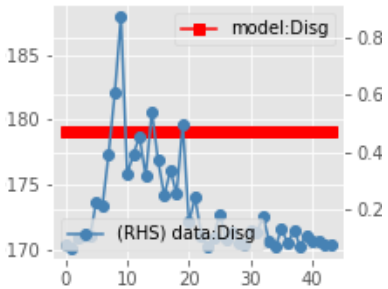


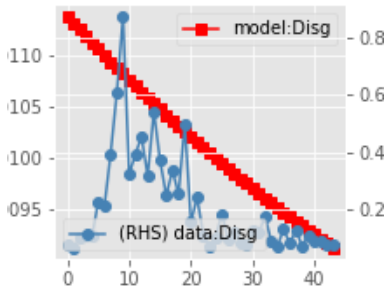


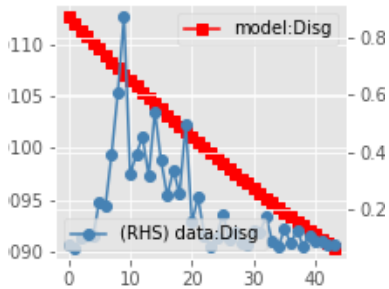


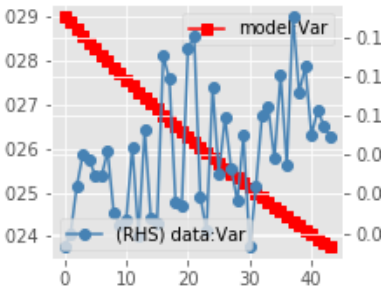


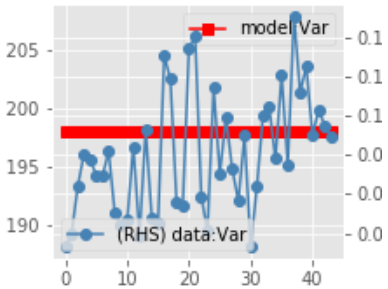


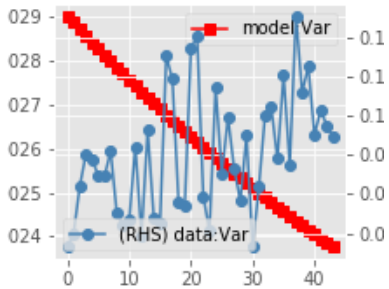


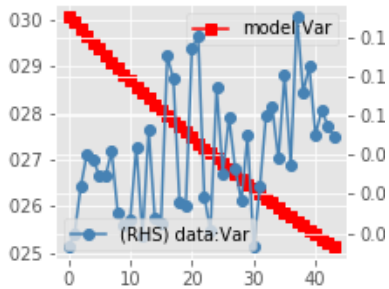






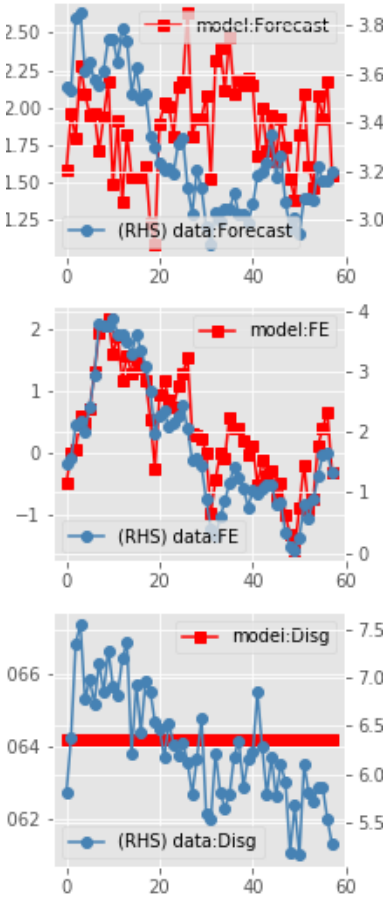




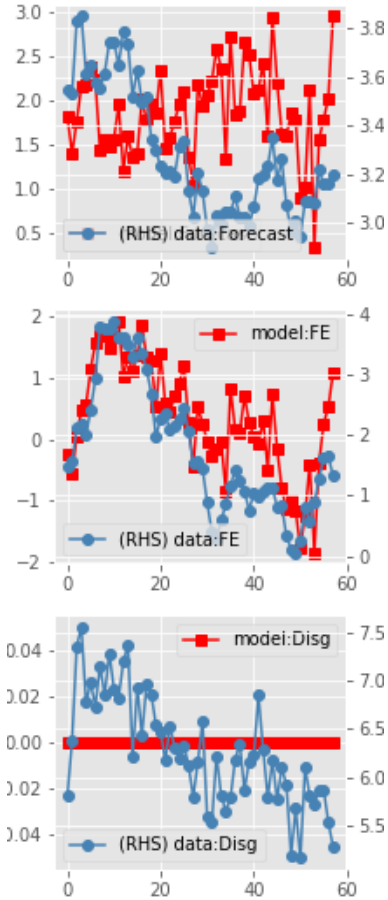


Households and NIAR

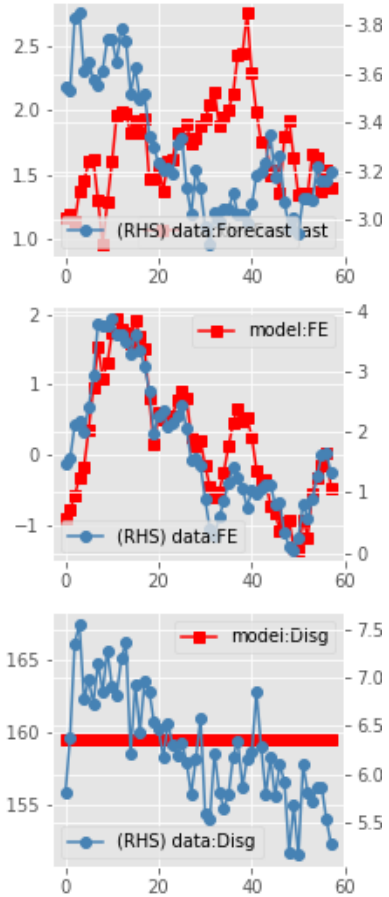
(a) FE



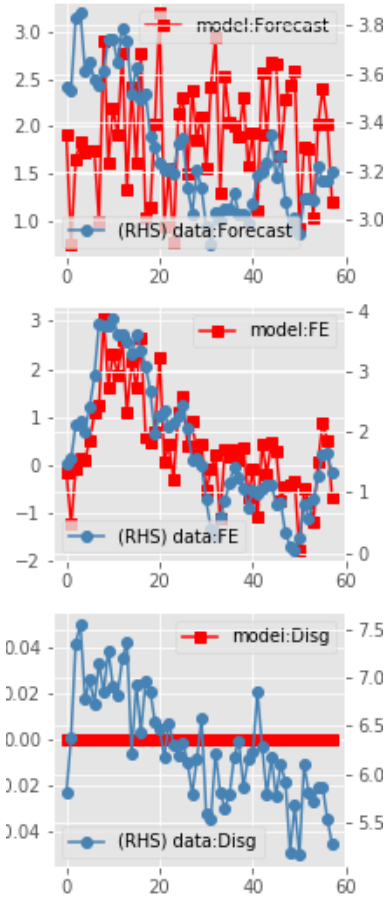
(b) Disg



(c) FE/Disg

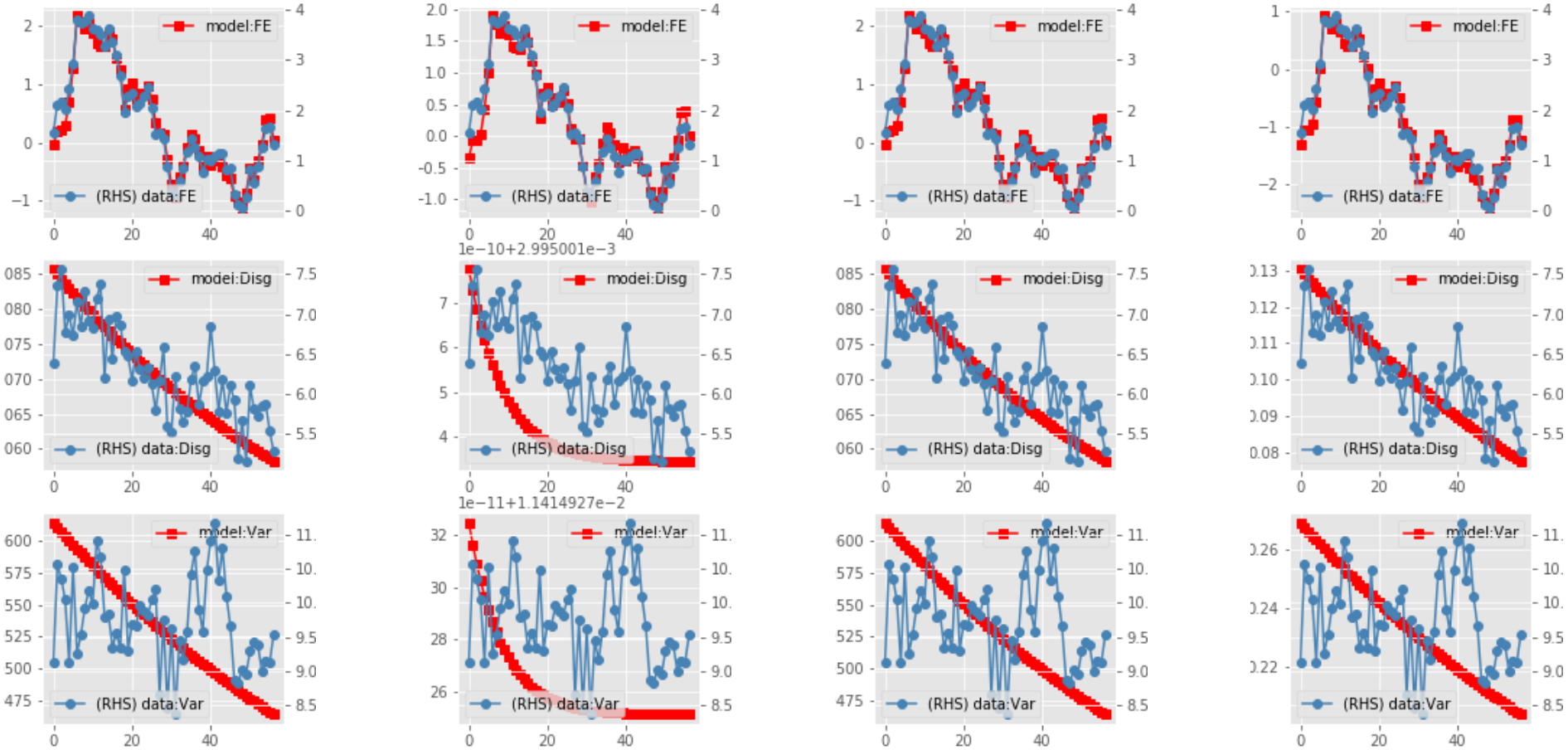


(d) FE/Disg/Var



Households and NIAR: joint estimates

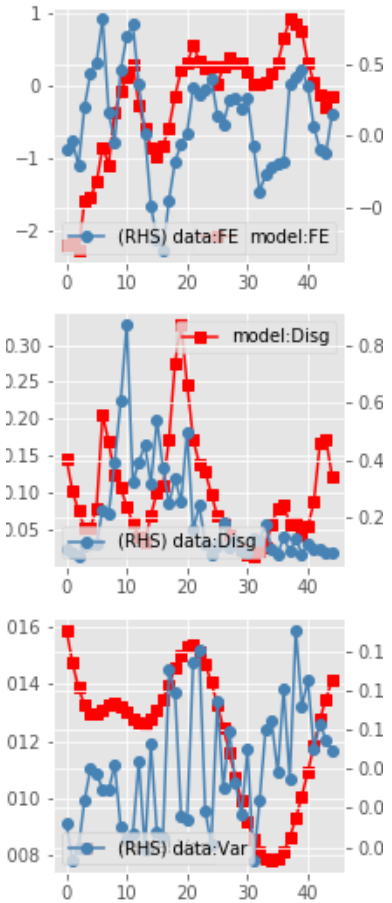
(a) FE (b) Disg (c) FE/Disg (d) FE/Disg/Var



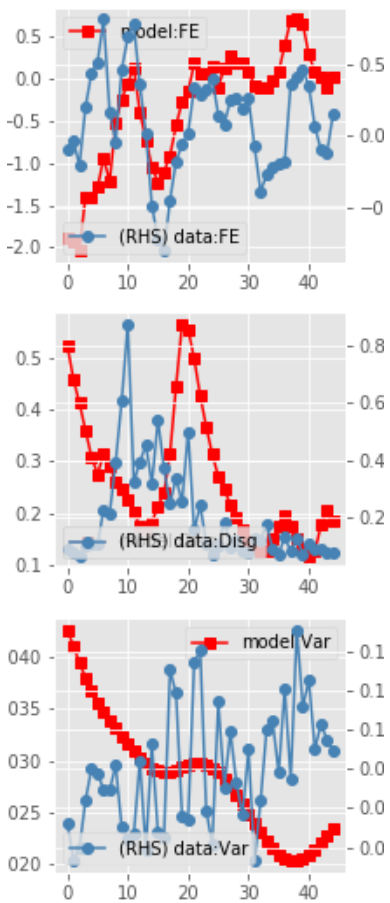
Outline

Professionals and SESV

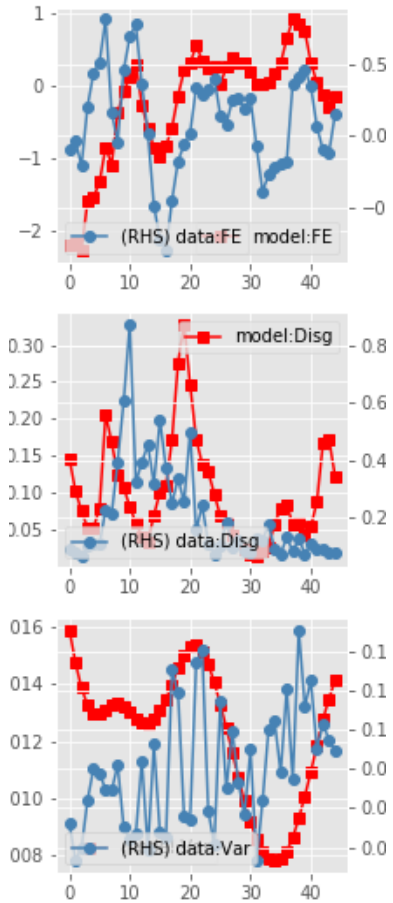
(a) FE



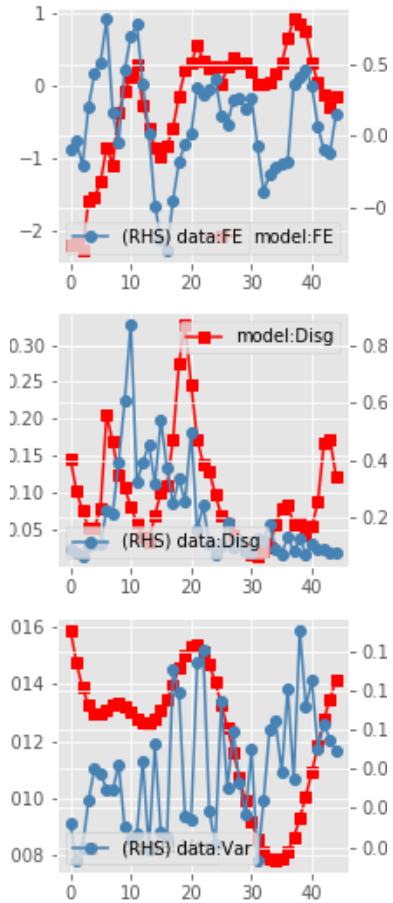
(b) Disg



(c) FE/Disg



(d) FE/Disg/Var



NIAR parameters

Table: SMM Estimates of Parameters of NI

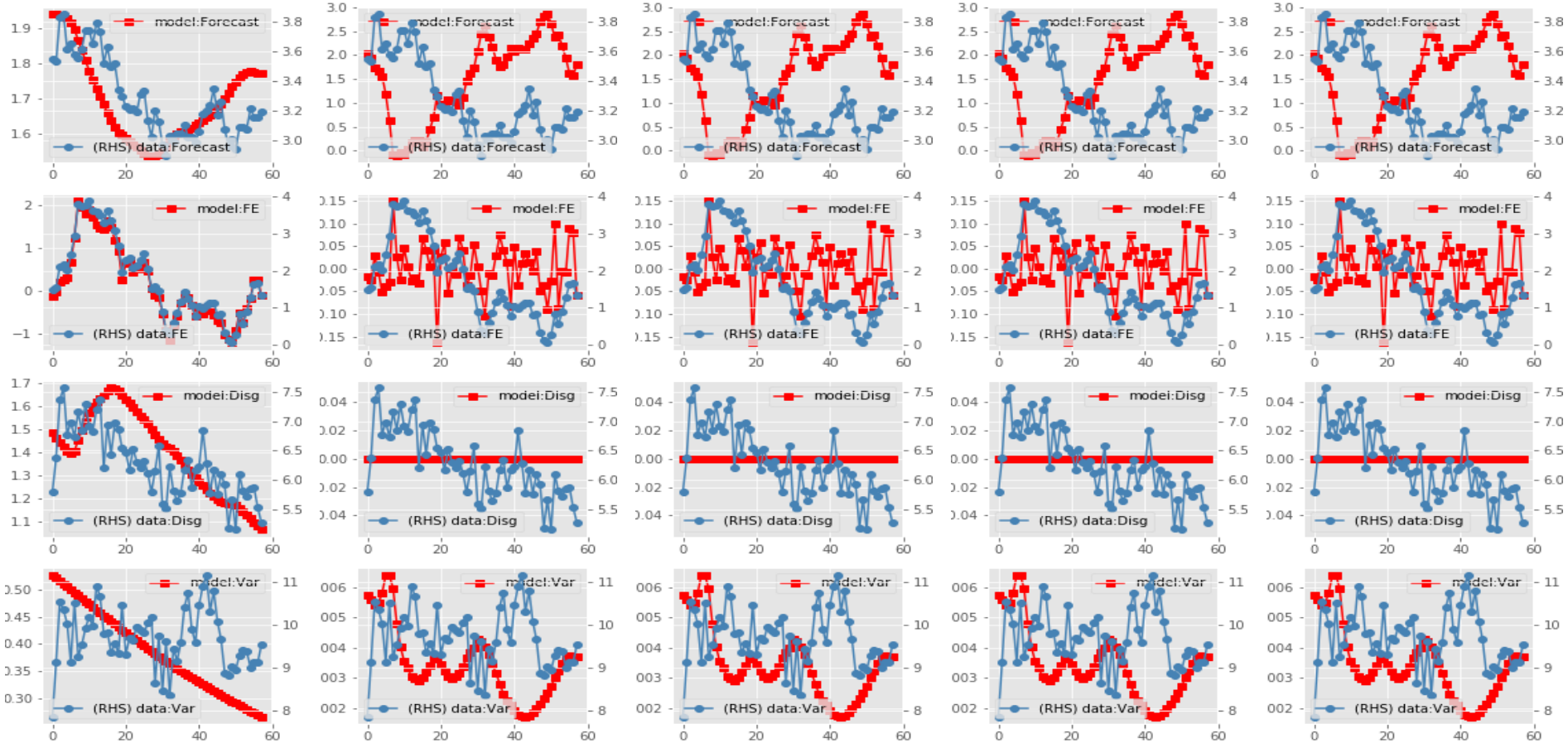
0	1	2	3	4	NI: $\hat{\sigma}_{pb,SPF}$	$\hat{\sigma}_{pr,SPF}$
FEVar	FEATV				25.32	16.07
DisgVar	DisgATV				471301.73	0.85
FEVar	FEATV	DisgVar	DisgATV		25.32	16.07
FEVar	FEATV	DisgVar	DisgATV	Var	9.16708E+12	2.37

- σ_{pb}: noisiness of public signals in NI
- σ_{pr}: noisiness of private signals in Ni

Outline

Results: households and SESV

(a) forecast (b) FE (c) forecast/FE (d) FE/var (e) FE/var/Disg



SESV parameters

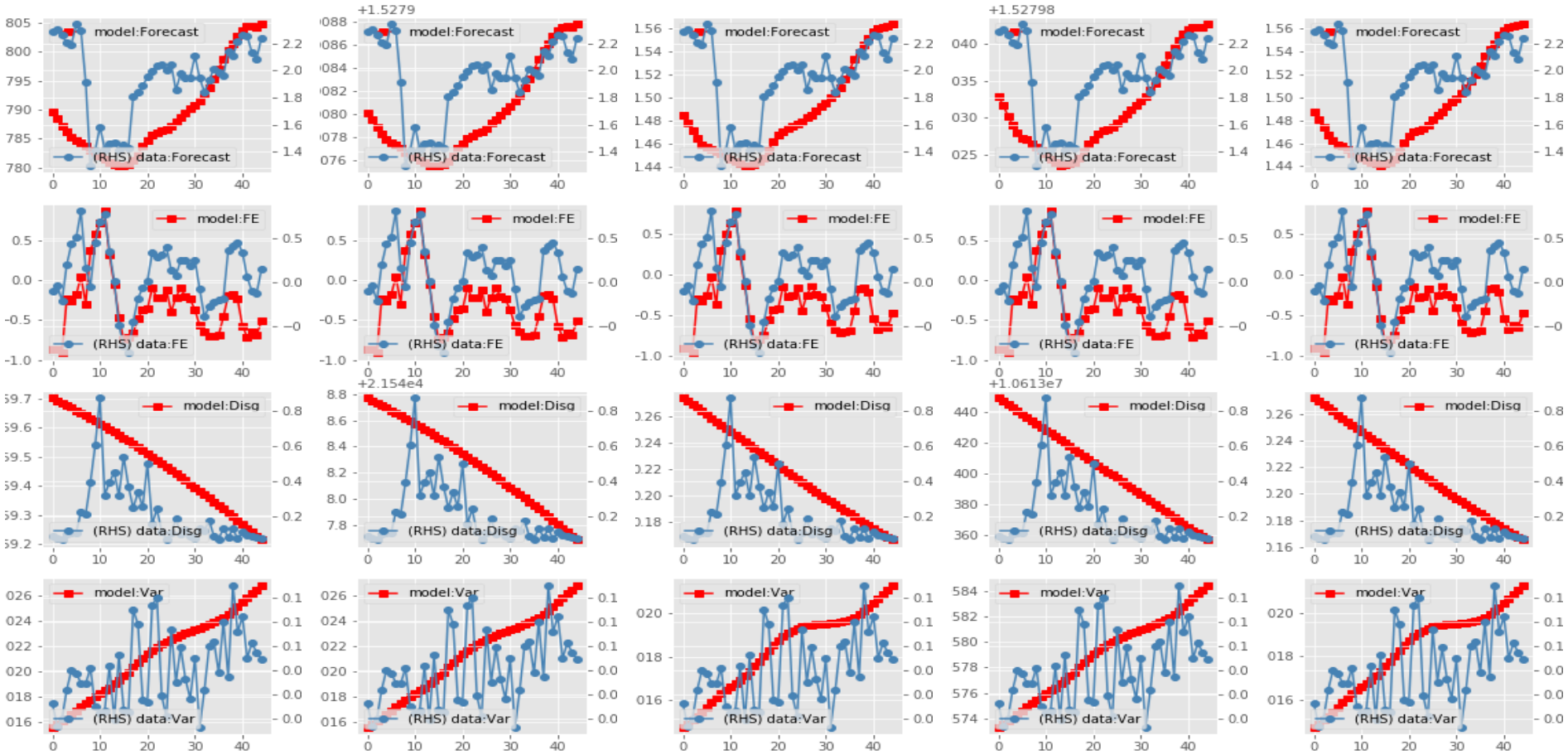
Table: Minimum Distance Estimates of Parameters of SESV

0	1	2	SE: $\hat{\lambda}_{SPF}$(Q)	SE: $\hat{\lambda}_{SCE}$(M)
Forecast			0.1	0.02
FE			0.12	1
FE	Disg		0.14	1
FE	Var		0.12	1
FE	Disg	Var	0.14	1

- λ: update rate in SE

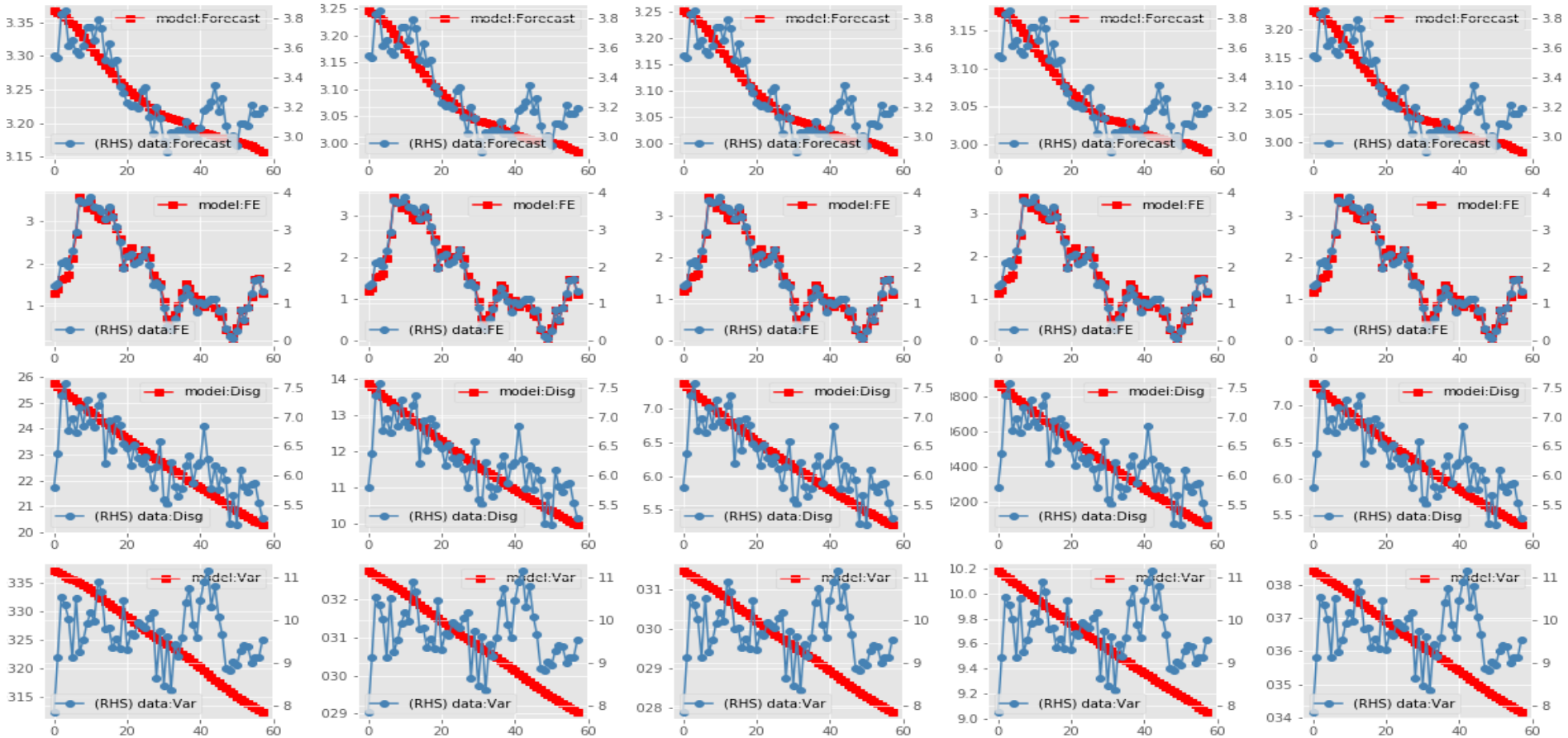
Results: professionals and NISV

(a) forecast (b) FE (c) forecast/FE (d) FE/var (e) FE/var/Disg



Results: households and NISV

(a) forecast (b) FE (c) forecast/FE (d) FE/var (e) FE/var/Disg



NISV parameters

Table: Minimum Distance Estimates of Parameters of NISV

0	1	2	NI: $\hat{\sigma}_{pb,SPF}$	$\hat{\sigma}_{pr,SPF}$	NI: $\hat{\sigma}_{pb,SCE}$	$\hat{\sigma}_{pr,SCE}$
Forecast			16.9	21.44	5.21	6.05
FE			67.05	146.8	4.4	4.88
FE	Disg		62.6	0.57	7.23	3.54
FE	Var		787.17	3257.84	97.72	95.73
FE	Disg	Var	126.68	0.57	215.54	3.64

- σ_{pb}: noisiness of public signals in NI
- σ_{pr}: noisiness of private signals in NI

Ongoing work

- I have been matching time-specific conditional moments with data. I will match unconditional moments
- jointly estimate process parameters and expectation formation parameters
- statistical tests of the fitness, i.e. Sargan–Hansen test in the GMM

Conclusion

- Sticky expectation (SE) matches data of inflation and expectations better compared to noisy information (NI)
- Within each model, households are more irrational compared to professionals
- Incorporating higher moments, i.e. uncertainty, helps "discipline" theories on expectation formation
- Higher moments from surveys also contain useful information about the inflation dynamics itself

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