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

Tao Wang
Johns Hopkins University

December 5, 2019

Outline

1. Motivation
2. Theory
3. Estimation
   - AR(1)
   - Stocastic volatility
4. Conclusion

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

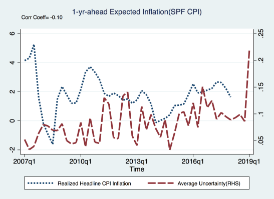
Individual moments	Population moments
Mean forecast: $y_{i,t+h\|t}$	Average forecast: $\bar{y}_{t+h\|t}$
Forecast error: $FE_{i,t+h\|t}$	Average forecast error: $\overline{FE}_{t+h\|t}$
Uncertainty: $Var_{i,t+h\|t}$	**Average uncertainty**: $\overline{Var}_{t+h\|t}$
	Disagreement: $\overline{Disg}_{t+h\|t}$

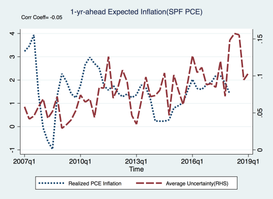
Data

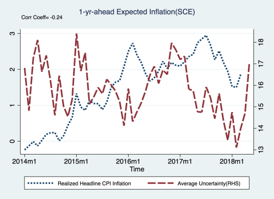
	SCE	SPF
Time period	2013M6-2018M6	2007Q1-2018Q4
Frequency	Monthly	Quarterly
Sample Size	1,300	30-50
Aggregate Var in Density	1-yr-ahead inflation	1-yr and 3-yr core CPI and core PCE
Pannel Structure	stay up to 12 months	average stay for 5 years
Demographic Info	Education, Income, Age	Industry

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

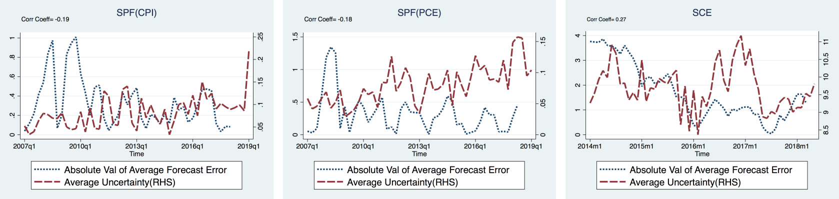
Basic patterns: uncertainty and realized inflation





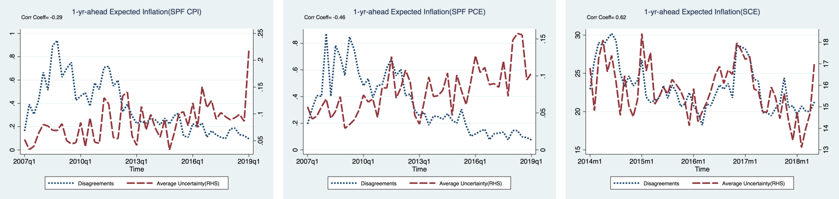


Basic patterns: uncertainty and the size of forecast errors



- 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

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

Minimum distance estimation

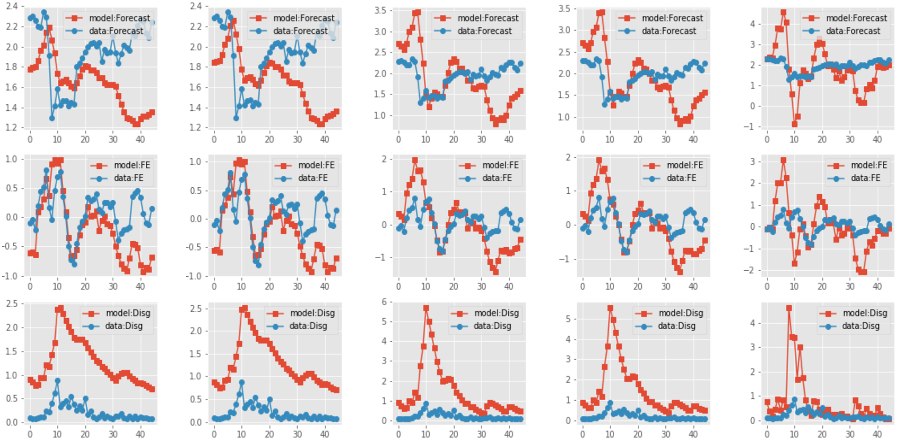
$$\widehat{\Omega} = \underset{\{\Omega \in \Gamma\}}{argmin} (M_{\mathrm{data}} - F^{o}(\Omega, Y)) W (M_{\mathrm{data}} - F^{o}(\Omega, Y))'$$

- Ω: parameters of the particular $o \in \{fire, se, ni\} \times \{ar, sv\}$
- Γ: constraints for the parameter.
- M_{data}: data moments
- F 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 to each point of the time t
- W: weight matrix, identity matrix for now

Outline

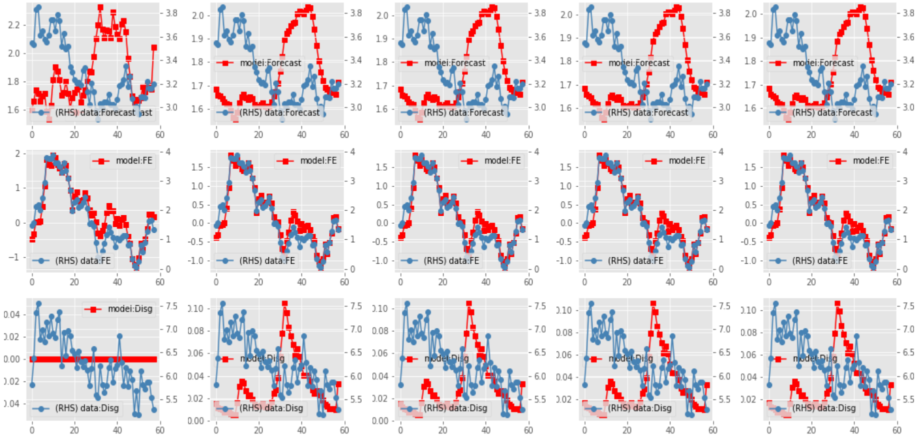
Results: professionals and SEAR

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



Results: households and SEAR

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



SE parameter estimate

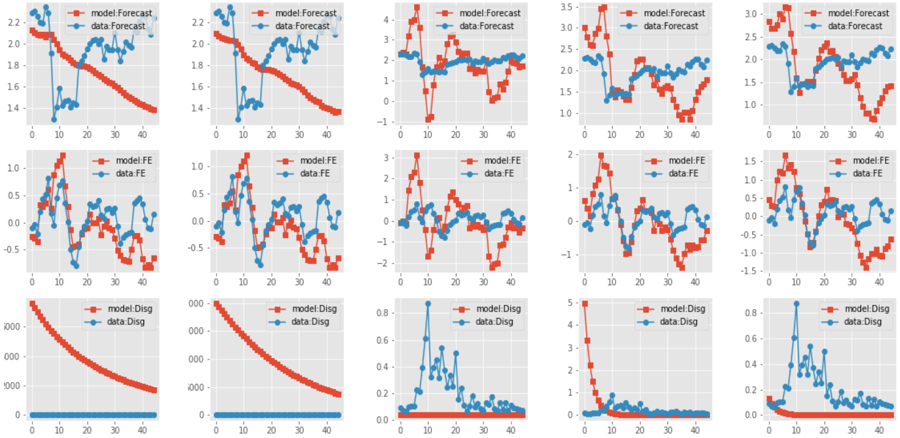
Table: Minimum Distance Estimates of Parameters of SE

0	1	2	SE: $\hat{\lambda}_{SPF}$(Q)	SE: $\hat{\lambda}_{SCE}$(M)
Forecast			0.04	1
FE			0.05	0.19
FE	Disg		0.17	0.19
FE	Var		0.16	0.18
FE	Disg	Var	0.53	0.18

- λ: update rate in SE

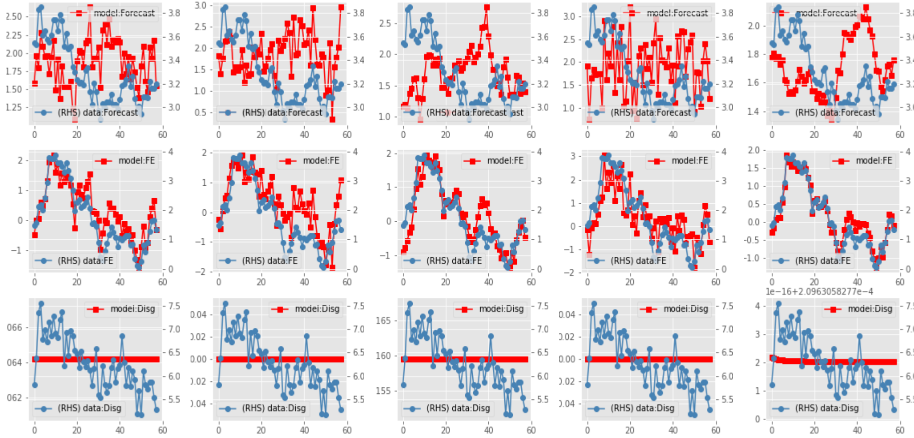
Results: professionals and NIAR

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



Results: households and NIAR

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



NIAR parameters

Table: Minimum Distance Estimates of Parameters of NI

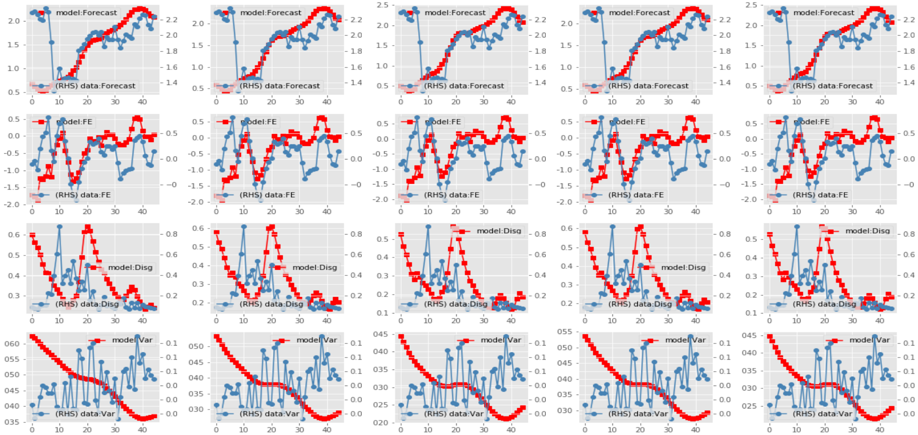
0	1	2	NI: $\hat{\sigma}_{pb,SPF}$	$\hat{\sigma}_{pr,SPF}$	NI: $\hat{\sigma}_{pb,SCE}$	$\hat{\sigma}_{pr,SCE}$
Forecast			39.65	192.22	2.35	0.38
FE			12.64	211.14	1.64	0
FE	Disg		112.37	0.34	512.51	0.86
FE	Var		1.13	367.43	0	1.28
FE	Disg	Var	1.29	29.84	2.74	127.86

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

Outline

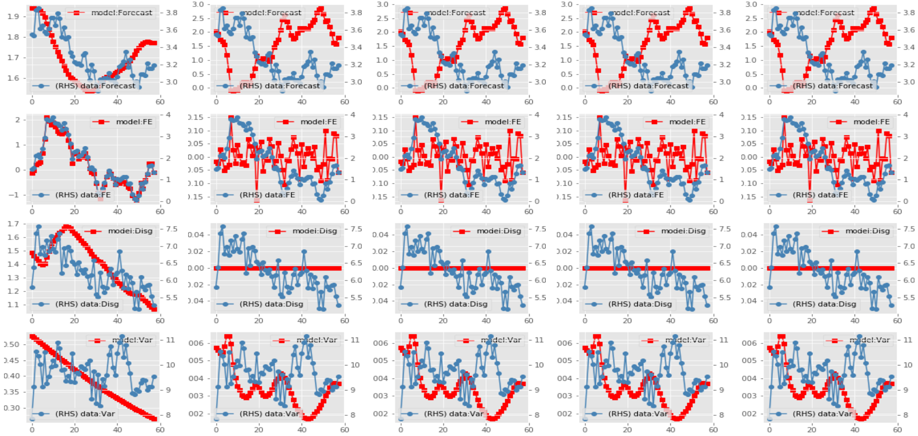
Results: professionals and SESV

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



Results: households and SESV

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



SESV parameters

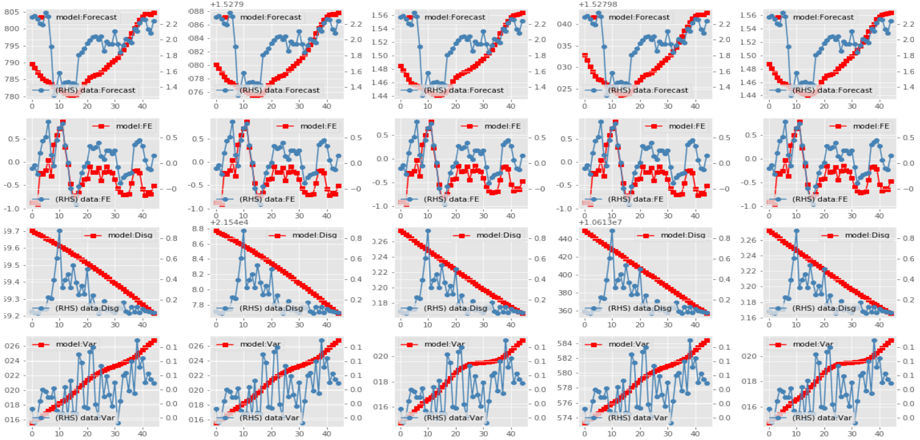
Table: Minimum Distance Estimates of Parameters of SESV

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

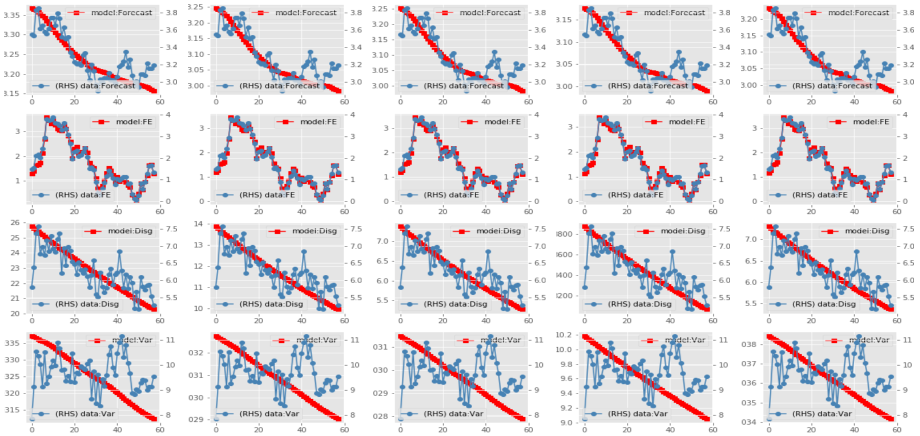
Results: professionals and NISV

(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

Bachmann, R., Elstner, S., and Sims, E. R. (2013). Uncertainty and economic activity: Evidence from business survey data. *American Economic Journal: Macroeconomics*, 5(2):217–49.

Bertrand, M. and Mullainathan, S. (2001). Do people mean what they say? implications for subjective survey data. *American Economic Review*, 91(2):67–72.

Binder, C. C. (2017). Measuring uncertainty based on rounding: New method and application to inflation expectations. *Journal of Monetary Economics*, 90:1–12.

Bloom, N. (2009). The impact of uncertainty shocks. *econometrica*, 77(3):623–685.

Branch, W. A. (2004). The theory of rationally heterogeneous expectations: evidence from survey data on inflation expectations. *The Economic Journal*, 114(497):592–621.

Carroll, C. D. (2003). Macroeconomic expectations of households and professional forecasters. *the Quarterly Journal of economics*, 118(1):269–298.

Coibion, O. and Gorodnichenko, Y. (2012). What can survey forecasts tell us about information rigidities? *Journal of Political Economy*, 120(1):116–159.

Das, S., Kuhnen, C. M., and Nagel, S. (2017). Socioeconomic status and macroeconomic expectations. Technical report, National Bureau of Economic Research.

Delavande, A. (2014). Probabilistic expectations in developing countries. *Annu. Rev. Econ.*, 6(1):1–20.

Delavande, A., Giné, X., and McKenzie, D. (2011). Measuring subjective expectations in developing countries: A critical review and new evidence. *Journal of development economics*, 94(2):151–163.

Engelberg, J., Manski, C. F., and Williams, J. (2009). Comparing the point predictions and subjective probability distributions of professional forecasters. *Journal of Business & Economic Statistics*, 27(1):30–41.

Fuhrer, J. C. (2018). Intrinsic expectations persistence: evidence from professional and household survey expectations.

Jurado, K., Ludvigson, S. C., and Ng, S. (2015). Measuring uncertainty. *American Economic Review*, 105(3):1177–1216.

Malmendier, U. and Nagel, S. (2015). Learning from inflation experiences. *The Quarterly Journal of Economics*, 131(1):53–87.

Mankiw, N. G., Reis, R., and Wolfers, J. (2003). Disagreement about inflation expectations. *NBER macroeconomics annual*, 18:209–248.

Manski, C. F. (2004). Measuring expectations. *Econometrica*, 72(5):1329–1376.

Manski, C. F. (2018). Survey measurement of probabilistic macroeconomic expectations: progress and promise. *NBER Macroeconomics Annual*, 32(1):411–471.

Patton, A. J. and Timmermann, A. (2010). Why do forecasters disagree? lessons from the term structure of cross-sectional dispersion. *Journal of Monetary Economics*, 57(7):803–820.

Stock, J. H. and Watson, M. W. (2007). Why has us inflation become harder to forecast? *Journal of Money, Credit and banking*, 39:3–33.

Van der Klaauw, W., Bruine de Bruin, W., Topa, G., Potter, S., and Bryan, M. F. (2008). Rethinking the measurement of household inflation expectations: preliminary findings. *FRB of New York Staff Report*, (359).