Household Belief Formation in Uncertain Times

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August 26^{th} 2024

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Uncertainty is the theme of the decade

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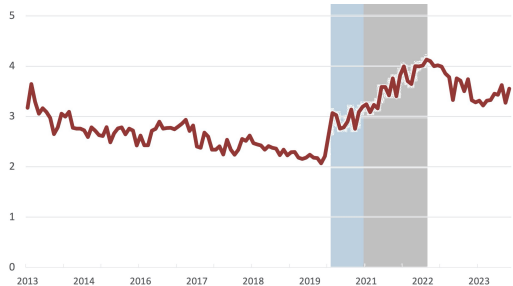
- Lately, significant increase in household uncertainty about the economy

Median 3-year ahead inflation uncertainty



Note: data from Survey of Consumer Expectations by the Federal reserve Bank of New York

How do households form beliefs in uncertain times?

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- **What we do**:
  - Estimate **belief rigidity** on survey of consumer expectations
    - i.e., how much HH rely on new vs existing info when forming beliefs
  - Use this novel measure to disentangle between uncertainty sources:
    1. **Uncertainty (noise) of information**
    2. **Uncertainty about fundamentals**
  - Explore relationship b/ **uncertainty** and **belief rigidity** in time series & cross section

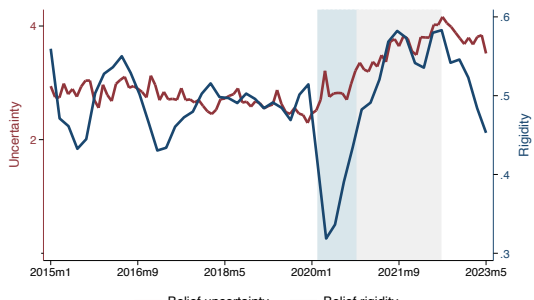
Results

1. Document a **reversal in correlation** between uncertainty and rigidity
   - *COVID:* ↑ **uncertainty**, ↓ **rigidity**

   → Update beliefs *more* but more uncertain

   - *Post-COVID:* ↑ **uncertainty**, ↑ **rigidity**

   → Update beliefs *less* and more uncertain



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2. **Belief updating model** to distinguish between *uncertainty sources*
   - ↑ ***New info*** **noise** ⇒ ↑ **belief rigidity**
   - ↑ ***Fundamental*** **uncertainty** ⇒ ↓ **belief rigidity**

3. Document strong **empirical support** for the model's implications in survey data

Contribution to the literature

- **Macro uncertainty**: impact of uncertainty on macroeconomy and asset prices (Bloom et al. '12, Bruno and Shin, '15, Orlik and Veldkamp '15, Bianchi et al. '23, Gambetti et al '23)

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  $\rightarrow$ **Contribution:** provide statistics to distinguish between fundamental & information uncertainty

- **Information experiments:** Bayesian framework for inflation belief updating consistent with experimental behavior (Armantier et al. '16, Cavallo et al. 17, Ciubion et al. '18, Barron '20)

  $\rightarrow$ **Contribution:** use *naturally occurring* variation and confirm results outside RCT

Data

- SCE core survey, monthly with rotating panel $\approx$ 1,200 HH heads, 2013-2023
- Consider **inflation expectations** 3 years ahead
  - Robustness with 1-year horizon of inflation and house prices
- **Posteriors**: 3-year ahead expectations in current month t
  - **Mean**: point forecast
  - **Uncertainty**: variance of density forecast DF
- **Priors** 3-year ahead expectations in previous month $t-1$
  - Horizon differs by 1 month, but small compared to horizon
- **Socioeconomic controls:** gender, age, race, education, income, numeracy, tenure

General framework

- HH in t form belief $E_t^i[x_{t+h}]$ about inflation in $t+h$ using signal

$$s_t^i = x_{t+h} + e_t^i, \qquad e_t^i \sim N(0, \sigma_{e,t}^2) \tag{1}$$

  the noise can be partly private and common

- Assume HH posterior mean follows

$$E_t^i[x_{t+h}] = (1 - G_t) E_{t-1}^i[x_{t+h}] + G_t s_t^i \tag{2}$$

- This setting embeds different models, among which the Bayesian RE
- We define $1 - G_t$ as **belief rigidity**

Belief rigidity

- Under this general framework, we can recover the rigidity with

(Goldstein 23, Gemmi & Valchev 23, Benhima & Bolliger 23)

$$For_{i,t} = \alpha_t + \beta_t Prior_{i,t} + \Theta_{i,t} + err^i_t \tag{3}$$

  - $\Theta_{i,t}$: age, gender, race, income, education, **tenure** fixed effects (Kim & Binder 23)
  - γ_t: year-month fixed effect (in the subsample regression, otherwise 0)

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- β_t is an unbiased estimator of the belief rigidity $1 - G$
  - **Intuition:** $\uparrow$ belief rigidity $\Rightarrow \uparrow$ corr(posterior beliefs, prior beliefs), $\uparrow \hat{\beta}_t$

- Identification relies on *cross-sectional* variation $\rightarrow$ run each month to get $\hat{\beta}_t, \forall t$
  - Previous methods require long time series (Coibion & Gorodnishenko 12, 15)

Inflation belief rigidity

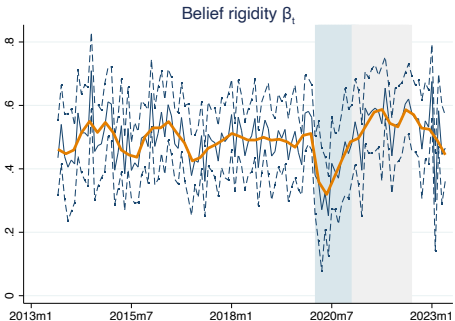

Figure: Cross-sectional regression by month

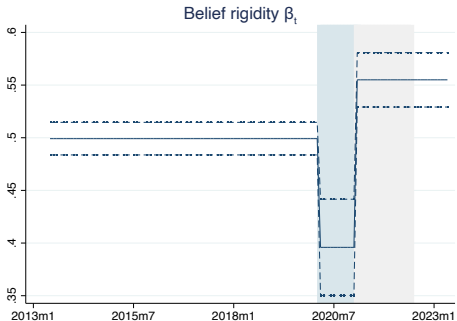

Figure: Panel regression by subsample

Table 1-year House prices Robustness Heterogeneity

Taking stock

1. *COVID outbreak:* ↑ **uncertainty**, ↓ **belief rigidity**

↪ Consumers update beliefs *more* but more uncertain

- **Lockdown** policies effect akin to lower cost of information, ↓ **uncertainty**, ↓ **rigidity**

→ Contributed to lowering belief rigidity, but not the whole story

Lockdown

2. *Post-COVID period:* ↑ **uncertainty**, ↑ **belief rigidity**

↪ Consumers update beliefs *less* and more uncertain

⇒ We interpret this evidence through the lens of a **model of belief formation**

Model of belief formation with 2 uncertainty sources

- General framework assume earlier

$$E_t^i[x_{t+h}] = (1 - G_t)E_{t-1}^i[x_{t+h}] + G_t s_t^i \tag{4}$$

- Posterior uncertainty:

$$\Sigma_{t+h,t} = (1 - G_t)^2 \Sigma_{t+h,t-1} + G_t^2 \sigma_{e,t}^2 \tag{5}$$

1. New information from signal $s_t^i = x_{t+h} + e_t^i$, where $e_t^i \sim N(0, \sigma_{e,t}^2)$
   - $\sigma_{e,t}^2$ is the **new information quality (noise)**

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   - $\sigma_{e,t}^2$ is the **new information quality (noise)**
2. Assume fundamental follows an AR(1) per Coibion & Gorodnishenko, (2015): $x_t = \rho x_{t-1} + u_t$, w/ $u \sim N(0, \sigma_{u,t}^2)$ then

$$\Sigma_{t+h,t-1} = \rho^2 \Sigma_{t+h-1,t-1} + \sigma_{u,t}^2 \tag{6}$$

   - $\sigma_{u,t}^2$ is the **fundamental uncertainty**, which increases prior uncertainty $\Sigma_{t+h,t-1}$

Different impact on rigidity

- Assume Bayesian updating, i.e. Rational Expectation

$$1 - G_t^{RE} = \frac{\sigma_{e,t}^2}{\sigma_{e,t}^2 + \underbrace{[\rho^2 \Sigma_{t+h-1,t-1} + \sigma_{u,t}^2]}_{\Sigma_{t+h,t-1}}} \tag{7}$$

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1. Increase in **new information noise** $\uparrow \sigma_{e,t}^2 \rightarrow \uparrow 1 - G_t^{RE}$
   - E.g. $\uparrow$ cost of collecting info or $\downarrow$ supply of info from newspaper or television
   - Empirically it fits the *post-COVID* period

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   - E.g. $\uparrow$ cost of collecting info or $\downarrow$ supply of info from newspaper or television
   - Empirically it fits the *post-COVID* period
2. Increase in **fundamental uncertainty** $\uparrow \sigma_{u,t}^2 \rightarrow \downarrow 1 - G_t^{RE}$
   - E.g. $\uparrow$ volatility of fundamental shock that makes current information obsolete
   - Empirically it fits the initial *COVID outbreak* period

$\Rightarrow$ Results shared also by large class of behavioral models (DE, overconfidence, . . .)

Testing the model

- Model's implications
  - ↑ ***New info*** **noise** ⇒ ↑ **belief rigidity**
  - ↑ ***Prior*** **uncertainty** ⇒ ↓ **belief rigidity**
- Comparison with findings in experimental literature
  - × *House price* and *labor market*, opposite effect or no effect
    (Armona et al 2019, Conlon et al 2018, Fuster et al 2022)
  - √ *Inflation* and *abstract* experiments support the model
    (Armantier et al 2016, Cavallo et al 2017, Coibion et al 2018, Coutts 2019, Barron 2020)

⇒ We test it using *naturally occurring* variation → no external validity concerns

⇒ **New info noise** not observed: we use 3 different proxies

1. Uncertainty and belief rigidity: posterior uncertainty

- Proxy **new info noise** with posterior uncertainty controlling for prior uncertainty

$$\underbrace{\Sigma_{t+h,t}}_{\text{post uncert}} = (1-G_t)^2 \underbrace{\Sigma_{t+h,t-1}}_{\text{prior uncert}} + G_t^2 \underbrace{\sigma^2_{e,t}}_{\text{new info noise}}$$

- Add interactions with *prior* and *posterior uncertainty* in previous regression

$$For_{i,j,t} = \alpha + \beta_1 Prior_{i,j,t} + \begin{bmatrix} Prior\ Uncert_{i,j,t} \times Prior_{i,j,t} \\ Post\ Uncertainty_{j,t} \times Prior_{i,j,t} \end{bmatrix}' \begin{bmatrix} \beta_2 \\ \beta_3 \end{bmatrix} + \\ + Z'_{i,j,t}\Gamma + \gamma_t + err_{i,j,t}$$

where $Z_{i,t}$ include the non-interacted variables

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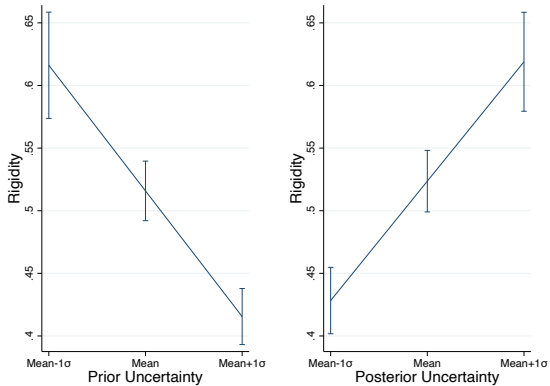
where $Z_{i,t}$ include the non-interacted variables

- Our hypotheses
  - $\beta_2 < 0$: **belief rigidity** decreases in **prior uncertainty**
  - $\beta_3 > 0$: **belief rigidity** increases in **info noise**

Evidence consistent with the theory and quant. large

- $\beta_2 < 0$: **belief rigidity** decreases in **prior uncertainty** (left panel)
- $\beta_3 > 0$: **belief rigidity** increases in **new info noise** (right panel)



1 year House prices Table

2. Uncertainty and belief rigidity: extracted noise

- A concern with the previous proxy: G_t depends on prior uncert and new info noise

$$\underbrace{\Sigma_{t+h,t}}_{\text{post uncert}} = (1 - G_t)^2 \underbrace{\Sigma_{t+h,t-1}}_{\text{prior uncert}} + G_t^2 \underbrace{\sigma^2_{e,t}}_{\text{new info noise}}$$

- We proceed in two steps
  1. Divide in $J = 24$ subsamples by socioeconomic characteristics and estimate $\hat{G}_t^j$

$$For_{i,j,t} = \alpha_{j,t} + \beta_{j,t} Prior_{i,t} + err_{i,j,t}, \qquad \hat{G}_t^j = 1 - \beta_{j,t}$$

  2. For each subsample, recover new info noise as

$$\widehat{\sigma}^j_{e,t} = \sqrt{\frac{\Sigma^j_{t+h,t} - (1 - \hat{G}_t^j)^2 \Sigma^j_{t+h,t-1}}{(\hat{G}_t^j)^2}}$$

Similar results, consistent with theory

- $\beta_2 < 0$: **belief rigidity** decreases in **prior uncertainty** (left panel)
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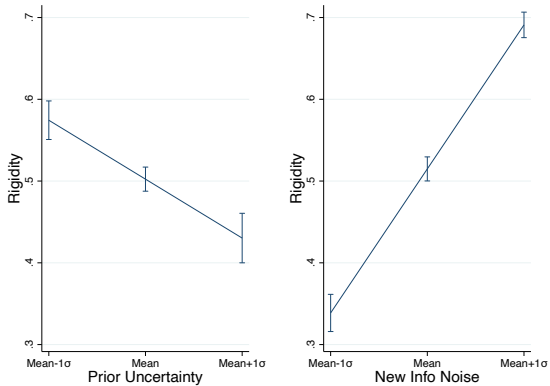

3. Uncertainty and belief rigidity: newspaper uncertainty

- Proxy for new info noise with Economic Policy Uncertainty (EPU) index by Baker et al (2022).
  - For each US state-month, from local to wide-ranging state newspapers, $\sim$ 3500 tot
  - Share of newspaper articles containing terms similar to '**economic**' and '**uncertain**'
  - Three indexes: *national* policies, *state* policies, and *composite*
- Take first-log difference in *national* EPU to isolate innovation and add to regression

Similar results, consistent with theory

- $\beta_2 < 0$: **belief rigidity** decreases in **prior uncertainty**
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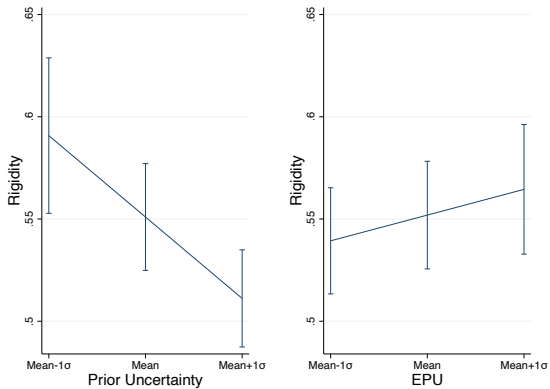


Implications

- Our finding in line with **Bayesian belief** updating:
  - HH update beliefs **more** when their **prior** is more uncertain
  - HH update beliefs **less** when **new information** is more uncertain
- Two important take-aways
  1. Similar results in recent RCT $\rightarrow$ confirm that this result has **external validity**
  2. Belief rigidity as statistic to distinguish between fundamental and new information uncertainty

Information frictions have macroeconomic consequences

- Derive the Phillips Curve with information frictions

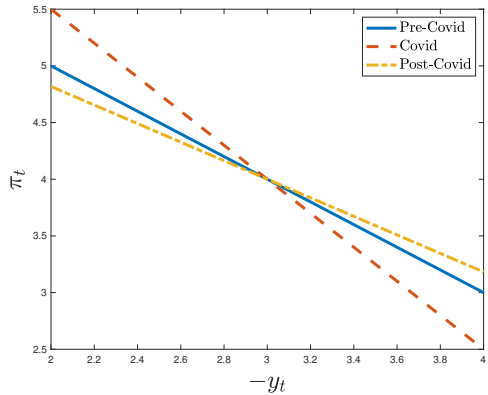
$$\underbrace{\pi_t}_{\text{inflation}} = \frac{G_t}{1-G_t} \underbrace{(y_t + \omega_t)}_{\text{Output + noise shock}}$$

1. $\downarrow$ **belief rigidity**, prices *more* responsive to shocks $\rightarrow$ PC **steeper**

2. $\uparrow$ **belief rigidity**, prices *less* responsive to shocks $\rightarrow$ PC **flatter**

- Opposite estimates in literature
  (Cerrato & Gitti, 2022; Gudmundsson et al., 2024)
  - Possible dumpening effect

Figure: Phillips Curve with estimated rigidity



Conclusions

- Document a reversal in **belief rigidity** in the **uncertain** post-pandemic economy
- Use **belief rigidity** to distinguish sources of uncertainty
  - **COVID outbreak:** ↓ **belief rigidity** due to ↑ ***fundamental* uncertainty** and **lockdown policies**
  - **Post-COVID:** ↑ **belief rigidity** due to ↑ ***new information* noise**
- Consumers belief updating empirically consistent with the theory
- Belief rigidity affects the Phillips Curve's slope → **different policy implications**

Appendix

Q9c

And in your view, what would you say is the percent chance that, **over the 12-month period between August 2015 and August 2016 ...**

Instruction H4.

the rate of inflation will be 12% or higher	____ percent chance
the rate of inflation will be between 8% and 12%	____ percent chance
the rate of inflation will be between 4% and 8%	____ percent chance
the rate of inflation will be between 2% and 4%	____ percent chance
the rate of inflation will be between 0% and 2%	____ percent chance
the rate of deflation (opposite of inflation) will be between 0% and 2%	____ percent chance
the rate of deflation (opposite of inflation) will be between 2% and 4%	____ percent chance
the rate of deflation (opposite of inflation) will be between 4% and 8%	____ percent chance
the rate of deflation (opposite of inflation) will be between 8% and 12%	____ percent chance
the rate of deflation (opposite of inflation) will be 12% or higher	____ percent chance
Total	**100**

Figure: SCE Question 24 from which we retrieve the uncertainty distribution

1 years inflation belief rigidity

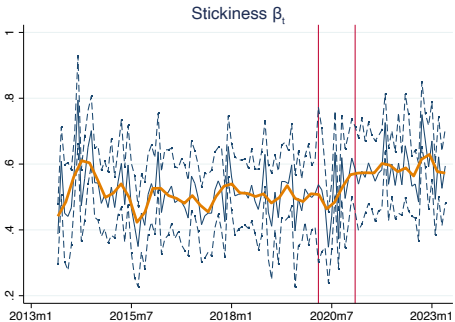


Figure: Cross-sectional regression by month

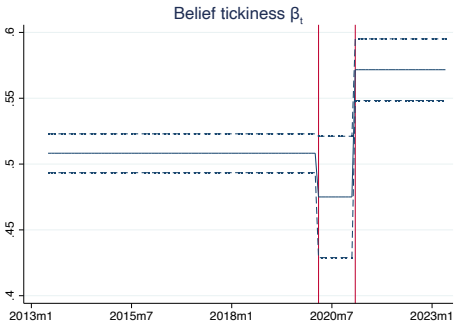


Figure: Panel regression by subsample

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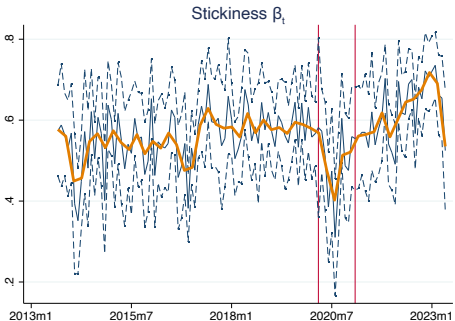
Housing prices belief rigidity



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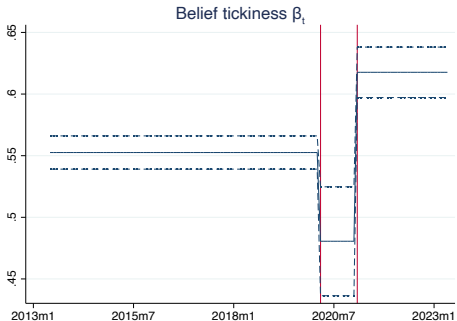

Figure: Panel regression by subsample

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RIGIDITY OF INFLATION BELIEFS: 3 YEARS

Table: Belief rigidity

	(1) *For 3y*	(2) *For 3y*	(3) *For 3y*
Prior 3y	0.515***	0.486***	0.474***
	(0.011)	(0.011)	(0.011)
Covid=1 × *Prior 3y*		-0.084***	-0.088***
		(0.028)	(0.026)
Post − *Covid*=1 × *Prior 3y*		0.082***	0.065***
		(0.019)	(0.018)
Constant	1.960***	2.039***	2.106***
	(0.049)	(0.037)	(0.037)
Year-Month FEs	Y	Y	Y
Age, Gender, Race FEs	Y	Y	Y
Tenure FEs	Y	Y	Y
Adjusted R-squared	0.33	0.33	0.31
Observations	83405	83405	80402

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RIGIDITY OF INFLATION BELIEFS: 1 YEAR

Table: Belief rigidity

	(1) *For 1y*	(2) *For 1y*	(3) *For 1y*
Prior 1y	0.518***	0.493***	0.477***
	(0.011)	(0.012)	(0.012)
Covid=1 × *Prior 1y*		-0.016	-0.015
		(0.035)	(0.034)
Post − *Covid*=1 × *Prior 1y*		0.072***	0.060***
		(0.019)	(0.020)
Constant	2.067***	2.101***	2.186***
	(0.047)	(0.041)	(0.043)
Year-Month FEs	Y	Y	Y
Age, Gender, Race FEs	Y	Y	Y
Tenure FEs	Y	Y	Y
Adjusted R-squared	0.39	0.39	0.37
Observations	82815	82815	79378

t

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RIGIDITY OF INFLATION BELIEFS: HOUSING PRICES

Table: Belief rigidity

	(1) *For H*	(2) *For H*	(3) *For H*
Prior H	0.548***	0.542***	0.535***
	(0.010)	(0.009)	(0.009)
Covid=1 × *Prior H*		-0.053*	-0.058*
		(0.031)	(0.032)
Post − *Covid*=1 × *Prior H*		0.040*	0.027
		(0.021)	(0.020)
Constant	2.378***	2.376***	2.423***
	(0.054)	(0.044)	(0.044)
Year-Month FEs	Y	Y	Y
Age, Gender, Race FEs	Y	Y	Y
Tenure FEs	Y	Y	Y
Adjusted R-squared	0.38	0.38	0.36
Observations	76724	76724	74807

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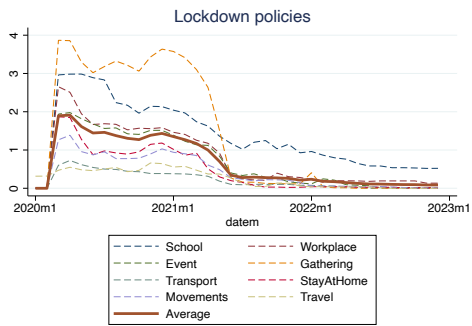
Information cost: the case of lockdowns

- Movement restrictions policy ⇒ lower marg cost of collecting info

  - Qualitative data on state-level **restriction policy intensity** *(OxCGRT database)*

  - Sample: Jan 2020 - Dec 2022

  - Control using state-level Covid *cases* and *death* per capita



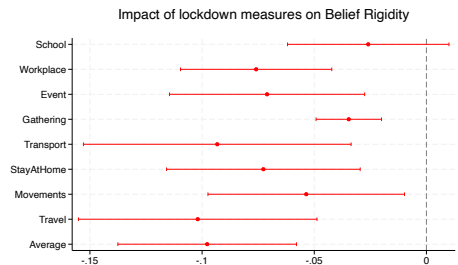
Information cost and belief rigidity

- We test how **lockdown** policies affect belief rigidity

$$For_{i,t} = \alpha + \beta_1 Prior_{i,t} + \beta_2 Prior_{i,t} \times LockdownIndex_{j,t} + \beta_3 LockdownIndex_{j,t}$$
$$Prior_{i,t} \times CovidImpact'_{j,t}\Pi + CovidImpact'_{j,t}\Gamma + \gamma_t + err^i_t$$

- β_2: impact of **lockdown** on **belief rigidity**

$\Rightarrow$ $\widehat{\beta}_2 < 0$: **lockdown** lowered belief rigidity



Estimates of β_2 for different indicators

Information cost and uncertainty

- We test how **lockdown** policies affect **belief uncertainty**
- Regress average *state-level* belief uncertainty on lockdown

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Figure: Impact of lockdown restrictions on uncertainty

	(1) $ln(Uncertainty3y)$	(2) $ln(Uncertainty3y)$	(3) $ln(Uncertainty3y)$	(4) $ln(Uncertainty3y)$
$Lockdown$	-0.181***	-0.188***	-0.208***	-0.090*
	(0.031)	(0.031)	(0.032)	(0.048)
$ln(DeathsCOVID)$			0.001	0.012
			(0.013)	(0.023)
$ln(CasesCOVID)$			-0.005	-0.021
			(0.016)	(0.028)
$EPUComposite$			0.006	-0.003
			(0.007)	(0.007)
Constant	1.201***	1.205***	1.181***	1.075***
	(0.032)	(0.019)	(0.092)	(0.130)
State FEs	N	Y	Y	Y
Sample	Mar20-May23	Mar20-May23	Mar20-May23	Mar20-Jun21
Adjusted R-squared	0.10	0.31	0.31	0.29
Observations	1715	1715	1705	799

- Consistent with increased reading habits, social media news demand, and TV viewership during Covid (Reuters Institute at UOxford, Nielsen, eMarketer, etc.)

Robustness

- √ Including commuting zone fixed effects
- √ Considering only consumers with high numeracy
- √ Considering only non-zero revisions (intensive margin)

Extensive margin Back

Extensive margin

Share of non-zero revisions a bit different (extensive margin)

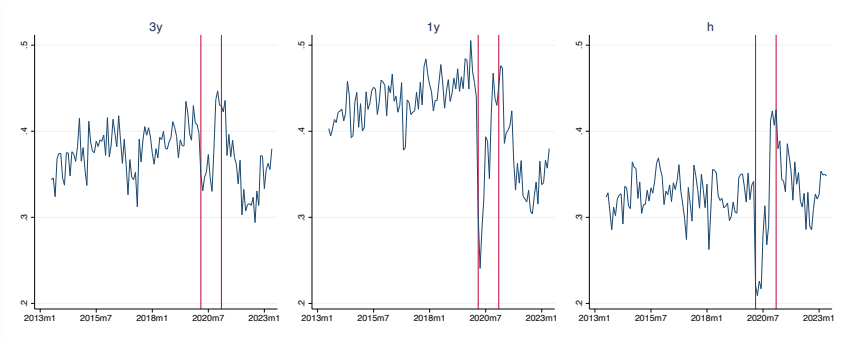

Figure: Monthly share of non-zero revisions

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rigidity and Uncertainty: posterior uncertainty

	(1) *For*	(2) *For*	(3) *For*	(4) *For*
PriorFor	0.534***	0.526***		0.548***
	(0.023)	(0.016)		(0.024)
PriorFor × *PriorUncert*	-0.124***		-0.131***	-0.125***
	(0.015)		(0.016)	(0.016)
PriorFor × *PostUncert*	0.116***		0.109***	0.113***
	(0.014)		(0.015)	(0.015)
PriorFor × *Prior Uncert 3y IQR*		-0.014***		
		(0.003)		
PriorFor × *Post Uncert 3y IQR*		0.010***		
		(0.003)		
Constant	0.501***	1.000***	2.793***	0.454***
	(0.095)	(0.082)	(0.083)	(0.098)
Year-Month FEs	Y	Y	Y	Y
Prior-Year-Month FEs	N	N	Y	N
Socio-demographic FEs	Y	Y	Y	Y
Non-interacted variables	Y	Y	Y	Y
Sample	Jun13-May23	Jun13-May23	Jun13-May23	excludeCOVID
Adjusted R-squared	0.36	0.37	0.37	0.37
Observations	90940	90940	90940	83563

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Rigidity and Uncertainty: EPU

	(1) *For*	(2) *For*	(3) *For*	(4) *For*	(5) *For*
PriorFor	0.296***	0.373***	0.396***		0.568***
	(0.040)	(0.034)	(0.025)		(0.123)
PriorFor × *PriorUncert* (*median*)	-0.197***			-0.189***	-0.210**
	(0.032)			(0.036)	(0.083)
PriorFor × *PriorUncert* (*mean*)		-0.262***			
		(0.023)			
PriorFor × *PriorUncert*			-0.127***		
			(0.012)		
PriorFor × *NewInfoNoise*(*median*)	0.192***			0.189***	0.080**
	(0.007)			(0.008)	(0.030)
PriorFor × *NewInfoNoise*(*mean*)		0.197***			
		(0.006)			
PriorFor × *NewInfoNoise*			0.101***		
			(0.004)		
Constant	1.205***	0.942**	1.213***	2.422***	0.396
	(0.415)	(0.450)	(0.085)	(0.341)	(0.419)
Year-Month FEs	Y	Y	Y	Y	Y
Non-interacted variables	Y	Y	Y	Y	Y
PriorxYear-Month FEs	N	N	N	Y	N
Sample	Jun13-May23	Jun13-May23	Jun13-May23	Jun13-May23	Jun13-May23
Adjusted R-squared	0.38	0.40	0.43	0.38	0.66
Observations	75639	74095	66193	75639	1021

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Rigidity and Uncertainty: extracted noise

	(1) *For*	(2) *For*	(3) *For*	(4) *For*
PriorFor	0.621***	0.621***	0.621***	0.634***
	(0.025)	(0.025)	(0.025)	(0.026)
PriorFor × *PriorUncert*	-0.049***	-0.049***	-0.049***	-0.052***
	(0.011)	(0.011)	(0.011)	(0.012)
PriorFor × Δ*ln*(*EPUnational*)	0.019**			
	(0.010)			
PriorFor × Δ*EPUcomposite*/100		0.027**		
		(0.013)		
PriorFor × Δ*EPUnational*/100			0.016	0.021**
			(0.010)	(0.009)
Constant	0.921***	0.923***	0.923***	0.882***
	(0.091)	(0.091)	(0.091)	(0.095)
Year-Month FEs	Y	Y	Y	Y
Non-interacted variables	Y	Y	Y	Y
Sociodemographic controls	Y	Y	Y	Y
Sample	Jun13-May23	Jun13-May23	Jun13-May23	excludeCOVID
Adjusted R-squared	0.33	0.33	0.33	0.34
Observations	90587	90757	90763	83404

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rigidity and Uncertainty: 1 year

	(1) *For 1y*	(2) *For 1y*	(3) *For 1y*	(4) *For 1y*
Prior 1y	0.537***	0.538***		0.551***
	(0.025)	(0.016)		(0.025)
Prior 1y × *PriorUncert*	-0.135***		-0.139***	-0.136***
	(0.013)		(0.013)	(0.014)
Prior 1y × *PostUncert*	0.129***		0.121***	0.125***
	(0.012)		(0.012)	(0.013)
Prior 1y × *Prior Uncert 1y IQR*		-0.014***		
		(0.003)		
Prior 1y × *Post Uncert 1y IQR*		0.009***		
		(0.003)		
Constant	0.642***	1.151***	3.144***	0.631***
	(0.085)	(0.068)	(0.081)	(0.090)
Year-Month FEs	Y	Y	Y	Y
Prior-Year-Month FEs	N	N	Y	N
Socio-demographic FEs	Y	Y	Y	Y
Non-interacted variables	Y	Y	Y	Y
Sample	Jun13-May23	Jun13-May23	Jun13-May23	excludeCOVID
Adjusted R-squared	0.44	0.44	0.45	0.46
Observations	90231	90231	90231	82857

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Rigidity and Uncertainty: house prices

	(1)	(2)	(3)	(4)
	For H	*For H*	*For H*	*For H*
Prior H	0.578***	0.577***		0.573***
	(0.022)	(0.014)		(0.022)
Prior H × PriorUncert	-0.153***		-0.154***	-0.144***
	(0.010)		(0.010)	(0.010)
Prior H × PostUncert	0.152***		0.148***	0.149***
	(0.011)		(0.011)	(0.012)
Prior H		0.000		
		(0.000)		
Prior H × Prior Uncert H IQR		-0.020***		
		(0.002)		
Prior H × Post Uncert H IQR		0.017***		
		(0.003)		
Constant	0.502***	1.142***	3.494***	0.535***
	(0.116)	(0.081)	(0.096)	(0.109)
Year-Month FEs	Y	Y	Y	Y
Prior-Year-Month FEs	N	N	Y	N
Socio-demographic FEs	Y	Y	Y	Y
Non-interacted variables	Y	Y	Y	Y
Sample	Jun13-May23	Jun13-May23	Jun13-May23	excludeCOVID
Adjusted R-squared	0.44	0.44	0.45	0.45
Observations	83475	83475	83475	76535

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rigidity and Uncertainty: the effect of numeracy skill

	(1) *For 1y*	(2) *For 1y*	(3) *For 1y*	(4) *For 1y*
Prior 1y	0.540***	0.519***	0.558***	0.556***
	(0.010)	(0.014)	(0.024)	(0.029)
High Numeracy$_{it}$=1 × Prior 1y		0.026	0.019	0.027
		(0.016)	(0.016)	(0.028)
Prior 1y × ln(Prior Uncert1y)			-0.156***	-0.088***
			(0.014)	(0.024)
Prior 1y × ln(Post Uncert1y)			0.131***	0.058***
			(0.013)	(0.019)
High Numeracy$_{it}$=1 × Prior 1y × ln(Prior Uncert1y)				-0.121***
				(0.024)
High Numeracy$_{it}$=1 × Prior 1y × ln(Post Uncert1y)				0.131***
				(0.023)
Constant	2.030***	2.745***	1.633***	1.528***
	(0.047)	(0.081)	(0.110)	(0.135)
Year-Month FEs	Y	Y	Y	Y
Socio-demographic FEs	Y	Y	Y	Y
Non-interacted variables	Y	Y	Y	Y
Adjusted R-squared	0.39	0.40	0.43	0.43
Observations	91127	91111	74315	74315

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Rigidity and Uncertainty: 1 year

- Evidence consistent with the theory and quantitatively large

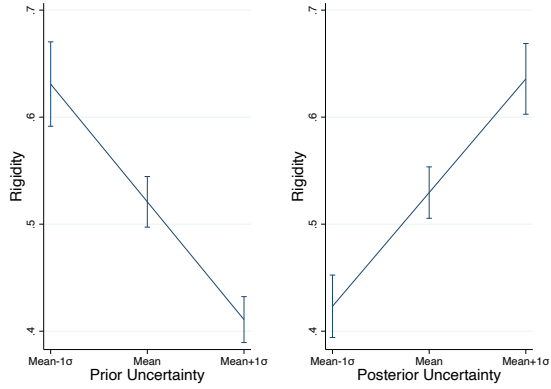

Figure: Belief rigidity and uncertainty

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Rigidity and Uncertainty: house prices

- Evidence consistent with the theory and quantitatively large

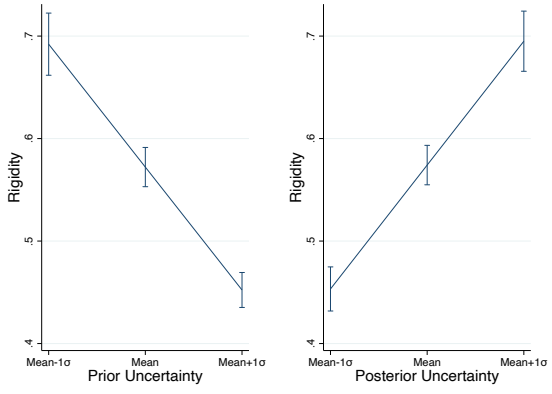

Figure: Belief rigidity and uncertainty

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Rigidity and Uncertainty: the effect of numeracy skill

$$
\begin{aligned}
For_{i,t} =& \alpha + \beta_1 Prior_{i,t} + \begin{bmatrix} Prior\ \ Uncertainty_{it} \times Prior_{i,t} \\ Post\ \ Uncertainty_{it} \times Prior_{i,t} \end{bmatrix}' \begin{bmatrix} \beta_2 \\ \beta_3 \end{bmatrix} \\
&+ High\ Numeracy_{i,t} \times \begin{bmatrix} Prior\ \ Uncertainty_{it} \times Prior_{i,t} \\ Post\ \ Uncertainty_{it} \times Prior_{i,t} \end{bmatrix}' \begin{bmatrix} \beta_4 \\ \beta_5 \end{bmatrix} \\
&+ Z'_{i,t}\Gamma + \Theta_{i,t} + \gamma_t + err^i_t
\end{aligned} \tag{8}
$$

- β_4 and β_5: effect of numeracy on the relation between uncertainty and rigidity

Effect of numeracy skill: 1y

- The evidence applies to high numeracy HH: more likely to be Bayesian? Table

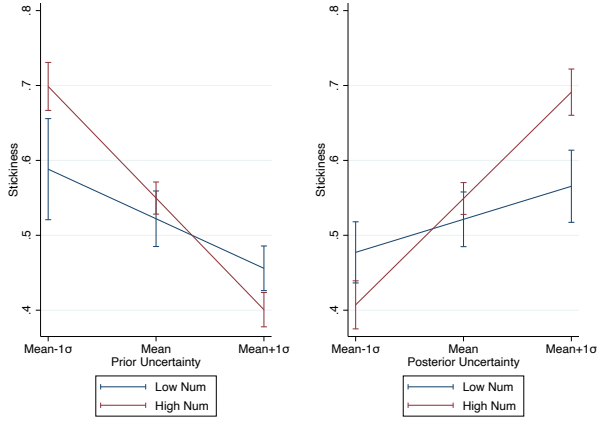
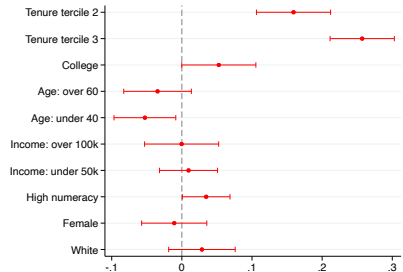


Figure: Belief rigidity and uncertainty for different numeracy skill

heterogeneity in Belief Rigidity

$$For_{i,t} = \alpha + \beta_1 Prior_{i,t} + \mathbf{X}_{i,t}\mathbf{B}_2 + Prior_{i,t} \times \mathbf{X}_{i,t}\mathbf{B}_3 + \gamma_t + err_t^i$$

Figure: Heterogeneity in belief rigidity



Legend: the figure shows the impact of socioeconomic characteristics on our estimate of belief rigidity, $\mathbf{B}_3$ in (44), i.e. column (7) of Table **??**. Sample period: 2020M3-2023M5.

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