Shock Transmission and the Sources of Heterogeneous Expectations

Alistair Macaulay
University of Oxford

August 2022

Motivation

- Expectations are heterogeneous (Mankiw et al, 2004; Dovern et al, 2012; etc. etc...).
- Policymakers (usually) focus on average expectations, ignore the dispersion.

Question: When and how does the heterogeneity affect macro shock transmission, beyond effects summarized by the average?

Motivation

- Expectations are heterogeneous (Mankiw et al, 2004; Dovern et al, 2012; etc. etc...).

- Policymakers (usually) focus on average expectations, ignore the dispersion.

Question: When and how does the heterogeneity affect macro shock transmission, beyond effects summarized by the average?

Key step: Heterogeneity could come from

1. **Information** - relax **full information** (Link et al, 2021).

2. **Subjective models** - relax **rational expectations** (Andre et al, 2022).

3. **Both** - (Macaulay & Moberly, 2022).

Answer: When information correlated with subjective models across agents.

Three contributions

1. **Decomposition:** novel transmission channel in general partial-equilibrium model: Cov(information, subjective models).

2. **Empirics:** document joint distribution of info & subjective models around inflation.

3. **Implications:** selective ‘baking in’ of expectations.

The Novel Transmission Channel

Earnings Heterogeneity (Auclert, 2019):

$$\text{Income} \xrightarrow[\text{MPC}]{} \text{Consumption}$$

- Shock amplified if the **shock** is concentrated among those who **react** the most to it.
- i.e. if $Cov(\text{shock exposure}, \text{MPC})$ is large.

The Novel Transmission Channel

Earnings Heterogeneity (Auclert, 2019):

$$\text{Income} \xrightarrow[\text{MPC}]{} \text{Consumption}$$

- Shock amplified if the **shock** is concentrated among those who **react** the most to it.
- i.e. if $Cov(\text{shock exposure, MPC})$ is large.

Narrative Heterogeneity:

$$\text{Information} \xrightarrow[\text{Model}]{} \text{Expectations} \longrightarrow \text{Action}$$

- Shock amplified if **information** on the shock is concentrated among those who **update other expectations** the most in response to it.
- i.e. if $Cov\left(\frac{\partial \mathbb{E}_t^i x_t}{\partial x_t}, \frac{d\mathbb{E}_t^i z_t}{d\mathbb{E}_t^i x_t}\right)$ is large.

Why narrative? Illustration sketch proof

What kind of data do we need?

Problem: data on **expectations** conflates information and models.

Solution: unique questions in the Bank of England Inflation Attitudes Survey.

- Repeated cross-section, quarterly since 2001. $\approx$ 4000 households each Q1, $\approx$ 2000 in other quarters.

What kind of data do we need?

Problem: data on **expectations** conflates information and models.

Solution: unique questions in the Bank of England Inflation Attitudes Survey.

- Repeated cross-section, quarterly since 2001. $\approx$ 4000 households each Q1, $\approx$ 2000 in other quarters.

Subjective model only: If prices started to rise faster than they are now, do you think Britain's economy would end up stronger, or weaker, or would it make little difference?

Detail

Information only: What were the most important factors in getting to your expectation for how prices in the shops would change over the next 12 months?

- Define indicator $= 1$ if select a direct information source. Detail

Demographic composition | Relationship to planned consumption

Fact 1: information and models in the cross-section[1]

	Info indicator
End up stronger	-0.00827
	(0.0192)
Make little difference	-0.0315**
	(0.0129)
Don't know	-0.0605***
	(0.0172)
HH controls	Yes
Time FE	Yes
Observations	8270

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

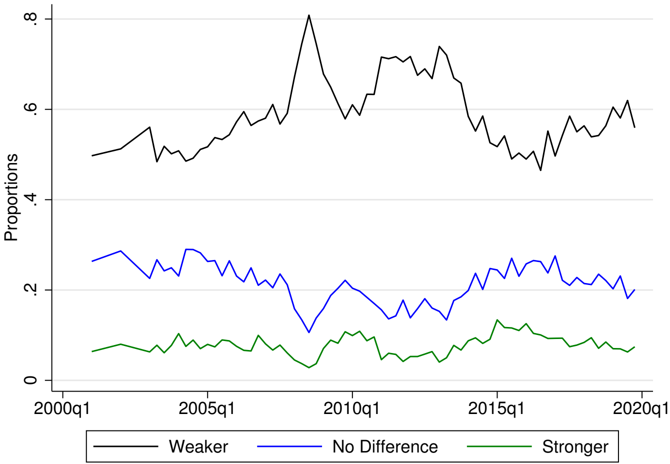
Fact 1: models where inflation...

- is positive vs. negative: **same** information.
- makes no difference: **less** information.

[1] Table shows average marginal effects from probit regression of info indicator on models. Omitted category: inflation makes the economy weaker.

Fact 2: models in the time series

Figure: Proportions with each response about how higher inflation would affect the strength of Britain's economy

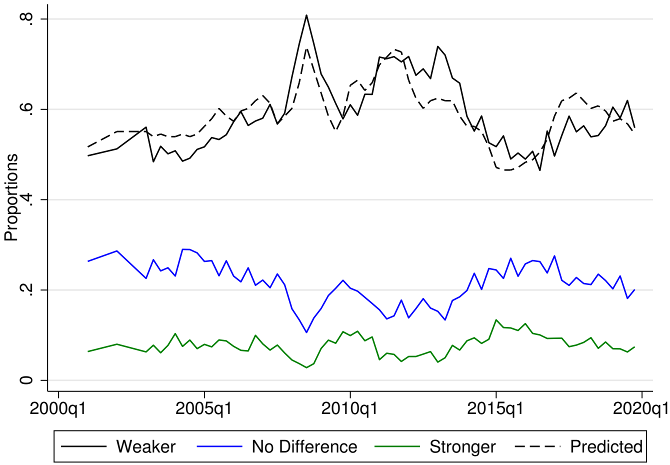


Modal answer: inflation makes the economy weaker.

$$\implies Cov(\text{info}, \frac{d\mathbb{E}^i y}{d\mathbb{E}^i \pi}) < 0$$

Fact 2: models in the time series

Figure: Proportions with each response about how higher inflation would affect the strength of Britain's economy



Modal answer: inflation makes the economy weaker.

$$\implies Cov(\text{info}, \frac{d\mathbb{E}^i y}{d\mathbb{E}^i \pi}) < 0$$

Dashed line: $\widehat{\Pr(\text{weaker})} = 0.057 \times \text{CPI inflation}_t + 0.466$

Fact 2: More households believe inflation weakens the economy when **realised inflation is high.**

$$Corr(\Pr(\text{weaker}), \pi_t) = 0.78$$

Perceived inflation by model

Model setup

Setup:

$$\max_{C_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(C_t) \quad \text{s.t.} \quad P_t C_t + B_t = R_{t-1} B_{t-1} + P_t Y_t$$

Log-quadratic approximation to objective function (lower case = log-deviation from steady state).

Subjective models:

$$\pi_t = \rho_\pi^i \pi_{t-1} + u_{\pi t}$$

$$r_t = \phi^i \pi_t + u_{rt}$$

$$y_t = \boldsymbol{\alpha^i} \pi_t + \lambda^i r_t + \rho_y^i y_{t-1} + u_{yt}$$

Model setup

Setup:

$$\max_{C_t, s_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(C_t) - \psi(\{s_t\}^t) \quad \text{s.t.} \quad P_t C_t + B_t = R_{t-1} B_{t-1} + P_t Y_t$$

Log-quadratic approximation to objective function (lower case = log-deviation from steady state).

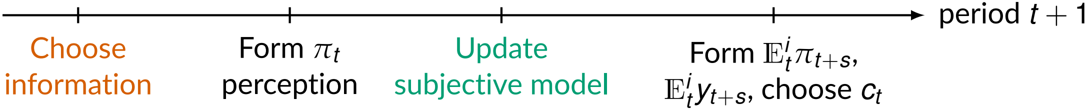
Subjective models:

$$\pi_t = \rho_\pi^i \pi_{t-1} + u_{\pi t}$$
$$r_t = \phi^i \pi_t + u_{rt}$$
$$y_t = \hat{\alpha}_t^i \pi_t + \lambda^i r_t + \rho_y^i y_{t-1} + u_{yt}$$

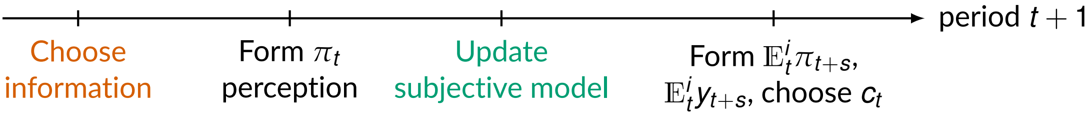
Key ingredients:

1. Information about current inflation is **costly**.
2. **Update** α^i with perceived inflation: $\hat{\alpha}_t^i = \alpha_0^i + \alpha_1^i \mathbb{E}_t^i \pi_t$. Microfoundation

Model timing



Model timing



Result 1: optimal information processing is increasing in $\left(\frac{dc_t^i}{d\mathbb{E}_t^i \pi_t}\right)^2$

- Intuition: information has more value if you believe it affects your choices.
- Matches cross-sectional data.

Model timing

Timeline → period $t+1$:

- Choose information
- Form π_t perception
- Update subjective model
- Form $\mathbb{E}_t^i \pi_{t+s}$, $\mathbb{E}_t^i y_{t+s}$, choose c_t

Result 1: optimal information processing is increasing in $\left(\frac{dc_t^i}{d\mathbb{E}_t^i \pi_t}\right)^2$

- Intuition: information has more value if you believe it affects your choices.
- Matches cross-sectional data.

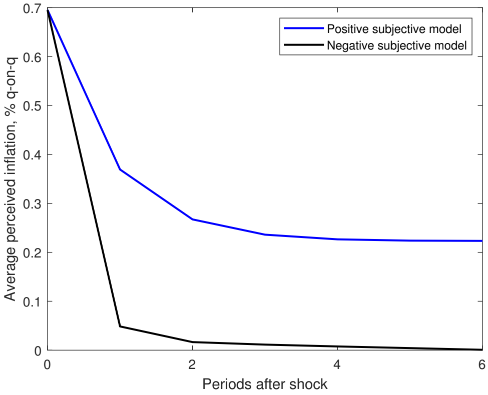
Result 2: high realised $\pi_t \implies$ lower average $\hat{\alpha}^i$ (if $\alpha_1^i < 0$).

- Matches time series data, + that $\mathbb{E}_t^i \pi_t$ is higher among those with negative models.

Perceived inflation by model

Extension: adding endogenous long-run expectations

Figure: Perceived π_t after 1% pt i.i.d. π_t shock



If start with **negative** model:

- $\pi_t \uparrow \implies$ subjective model gets even more negative.
- Pay more attention, quickly adjust $\mathbb{E}_t \pi_t$ down after shock.

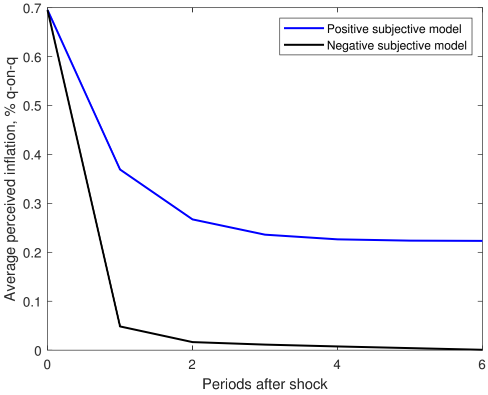
If start with **positive** model:

- $\pi_t \uparrow \implies$ subjective model updates towards 'inflation doesn't matter'.
- Pay less attention, **do not** adjust $\mathbb{E}_t \pi_t$ beliefs down after shock.

Empirical evidence Other implications

Extension: adding endogenous long-run expectations

Figure: Perceived π_t after 1% pt i.i.d. π_t shock



If start with **negative** model:

- $\pi_t \uparrow \implies$ subjective model gets even more negative.
- Pay more attention, quickly adjust $\mathbb{E}_t \pi_t$ down after shock.

If start with **positive** model:

- $\pi_t \uparrow \implies$ subjective model updates towards 'inflation doesn't matter'.
- Pay less attention, **do not** adjust $\mathbb{E}_t \pi_t$ beliefs down after shock.

Empirical evidence Other implications

Temporary shock $\implies$ **permanent** change in the narrative heterogeneity channel.

Conclusion

Heterogeneity in **expectations**: well-understood.

Heterogeneity in expectation **components**: the **narrative heterogeneity channel**.

The case of inflation:

- Narrative heterogeneity reduces $\frac{dc_t}{d\pi_t}$.
- Rational inattention + endogenous subjective models explains cross-sectional and time-series patterns.
- $\Longrightarrow$ selection in attention, time-varying transmission, selectively baked-in expectations.

Why 'narrative heterogeneity'? Back

Gibbons & Prusak (2020 AEA P&P): a narrative is a pair (situation, action)

$$\text{“}\underbrace{\text{Prices are currently rising}}_{\text{information}}\text{, so my salary buys less, }\underbrace{\text{therefore I should spend less}}_{\text{how I should react}}\text{”}$$

Appropriate action depends on **subjective model** - how you use information to update expectations.

Implication: Different info & models between households $\equiv$ different narratives.

Relationship to Shiller (2017) etc.

Relationship to narrative economics literature Back

Shiller (2017 AER):

> *"We have to consider the possibility that sometimes the dominant reason why a recession is severe is related to the* ***prevalence and vividness of certain stories****, not the purely economic feedback or multipliers that economists love to model."*

This paper: the **distribution** of narratives also matters.

- Shiller (and subsequent lit.): which narratives spread, and how.
- This paper: how narratives affect macro *given* spread.

Eliaz and Spiegler (2020 AER):

- Narrative is a *causal chain* represented by a DAG.
- DAG is a subjective model, with restriction that it must be **recursive**.

Why does information-model interaction matter? Illustration Back

Suppose there are 2 groups of households:

	Blue	Red
Effect of π on real income	0	↓
$\frac{\partial c^h}{\partial \mathbb{E}^h \pi}$	↑↑	↓

Why does information-model interaction matter? Illustration Back

Suppose there are 2 groups of households:

		Blue	Red	
Effect of π on real income		0	↓	
$\frac{\partial c^h}{\partial \mathbb{E}^h \pi}$		↑↑	↓	
$\frac{\partial \mathbb{E}^h \pi}{\partial \pi}$	Blue informed	1	0	$\Longrightarrow dc/d\pi > 0$
	Red informed	0	1	$\Longrightarrow dc/d\pi < 0$

When households differ in response to information, it matters who gets the information.

Why does information-model interaction matter? Illustration

Back

Suppose there are 2 groups of households:

			Blue	Red	
Effect of π on real income			0	$\downarrow$	
$\dfrac{\partial c^h}{\partial \mathbb{E}^h \pi}$			$\uparrow\uparrow$	$\downarrow$	
$\dfrac{\partial \mathbb{E}^h \pi}{\partial \pi}$	$\{$	Blue informed	1	0	$\implies dc/d\pi > 0$
		Red informed	0	1	$\implies dc/d\pi < 0$

When households differ in response to information, it matters who gets the information.

But different models $\implies$ different incentives to acquire information.
\+ different information $\implies$ different subjective models.

Expect systematic info-model relationships.

The narrative heterogeneity channel: a general model Back

Log-linear policy function: $\underbrace{\boldsymbol{x}_t^h}_{\text{choices}} = \underbrace{\boldsymbol{\mu}_t^h}_{\text{preferences}} \cdot \underbrace{\mathbb{E}_t^h \boldsymbol{z}_t^h}_{\text{expected external variables}}$

How does each expected variable respond to a shock?

$$\frac{d\mathbb{E}_t^h z_{it}^h}{dz_{nt}^h} = \underbrace{\left.\frac{d\mathbb{E}_t^h z_{it}^h}{dz_{nt}^h}\right|_{\mathbb{E}_t^h z_{j\neq i,t}}}_{\text{direct info } \delta_{int}^h} + \sum_{j\neq i}^{N_z} \underbrace{\frac{\partial \mathbb{E}_t^h z_{it}^h}{\partial \mathbb{E}_t^h z_{jt}^h}}_{\text{subj. model } \mathcal{M}_{ijt}^h} \cdot \frac{d\mathbb{E}_t^h z_{jt}^h}{dz_{nt}^h}$$

$$\implies \frac{d\mathbb{E}_t^h \boldsymbol{z}_t^h}{dz_{nt}^h} = \underbrace{\left(\boldsymbol{I} - \boldsymbol{\mathcal{M}}_t^h\right)^{-1}}_{\text{cross-learning } \chi_t^h} \delta_{nt}^h$$

Response of **aggregate** choice variable x_{kt} to the shock:

$$\frac{d\bar{x}_{kt}}{dz_{nt}} = \sum_{i=1}^{N_z}\sum_{j=1}^{N_z}\Big[\bar{\mu}_{ki,t}\bar{\chi}_{ij,t}\bar{\delta}_{jn,t} + Cov_H(\mu_{ki,t}^h, \chi_{ij,t}^h \delta_{jn,t}) + \underbrace{\bar{\mu}_{ki,t} Cov_H(\chi_{ij,t}^h, \delta_{jn,t}^h)}_{\textbf{narrative heterogeneity channel}}\Big]$$

Measuring subjective models Back

Question: If prices started to rise faster than they are now, do you think Britain's economy would end up stronger, or weaker, or would it make little difference?

How to interpret?

- Source of the shock? (Kamdar, 2019)
- Causal effects of inflation? (Andre et al, 2022)

Answer: it doesn't matter. All we need in the decomposition is $\chi^i_{y\pi,t} \equiv \frac{d\mathbb{E}^i y_{t+s}}{d\mathbb{E}^i \pi_t}$.

Responses indicate sign of cross-learning.

Demographic composition

Measuring information

Back

What were the most important factors in getting to your expectation for how prices in the shops would change over the next 12 months?

Reports of current inflation in the media
Discussion of the prospects for inflation in the media
} **Direct information**

The level of interest rates
The inflation target set by the government
The current strength of the UK economy
Expectations about how economic conditions in the UK are likely to evolve
How prices have changed in the shops recently, over the last 12 months
How prices have changed in the shops, on average, over the longer term i.e the last few years
Other factors
None
} **Cross-learning**

Define indicator $= 1$ if select a direct information source.

Other measures

Demographic variation in model beliefs and information Back

	Stronger	No Difference	Weaker	No information	Information
Age	46.28	49.18***	45.97**	47.65	47.09
Higher Education	0.28	0.24***	0.27**	0.30	0.33***
Income $> 25k$	0.40	0.37***	0.41***	0.43	0.43
Female	0.45	0.49***	0.53***	0.51	0.52
MP Knowledge	0.70	0.69	0.70	0.74	0.74

Stars denote significance of difference to 'stronger' group or 'No information' group. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. 'MP Knowledge' is a dummy variable $= 1$ if the respondent correctly identifies the Bank of England as the body responsible for setting base interest rates.

Multinomial logit of model beliefs on age, gender, class, employment status, income, education, region, homeownership, time FEs: pseudo-$R^2 = 0.035$ (models), $= 0.012$ (information)

Consumption plans, subjective models and information Back

Q: Which, if any, of the following actions are you taking, or planning to take, in the light of your expectations of price changes over the next twelve months?
b) cut back spending and save more.

Define *c* response indicator =1 if answer 'no'.

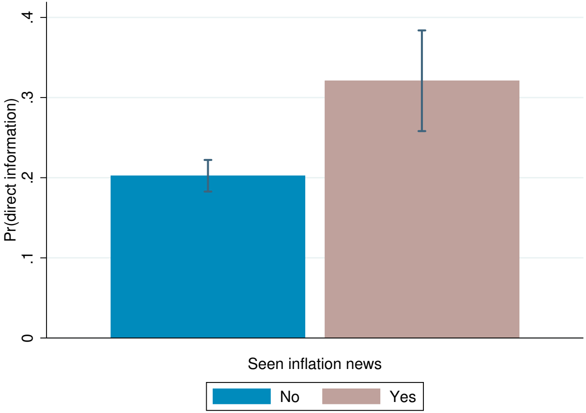
Table: probit regression of indicator on subj. models interacted with information, omitted category is 'weaker' & no direct info.

	c response to Eπ
information indicator=1	-0.213***
	(0.0611)
end up stronger	0.0108
	(0.0891)
information indicator=1 $\times$ end up stronger	0.348*
	(0.185)
make little difference	0.130**
	(0.0594)
information indicator=1 $\times$ little difference	0.0240
	(0.126)
HH controls	Yes
Time FE	Yes
Observations	4940

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Relationship of information indicator to other measures of direct information Back

Question: The latest CPI inflation figure was released on 12th February. Have you seen any reports, for example in the media, showing the latest inflation figure? (2013 Q1 only)[2]

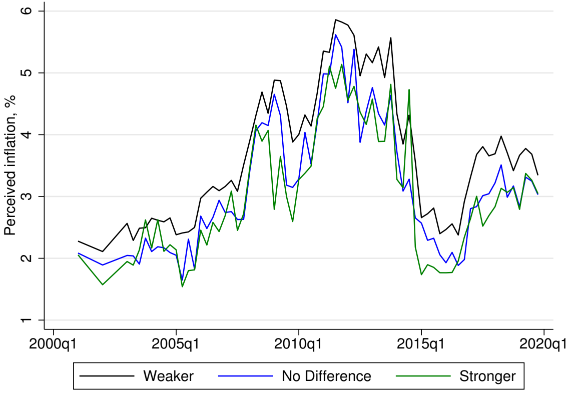


[2] Bars show weighted means of the information indicator. Lines show 90% confidence intervals.

Direction of causation? Back

If inflation $\implies$ models: Within a period, households with **higher** perceived inflation are **more negative** about the effects of inflation.

Figure: Inflation perception over past 12 months by subjective model



After household controls and time FEs, $\mathbb{E}_t^i \pi_t$ of a household with a **negative** model of inflation is:

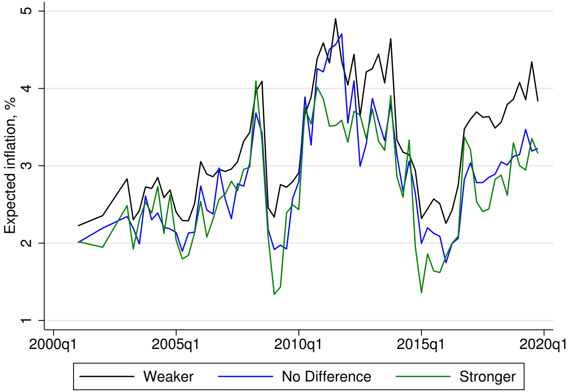
- 54 b.p. $>$ those with neutral model
- 70 b.p. $>$ those with positive model

Equivalent for expectations

Expectations by subjective model Back

Within a period, households with **higher** expected inflation are **more negative** about the effects of inflation.

Figure: Inflation expectation over next 12 months by subjective model



After household controls and time FEs, $\mathbb{E}_t^i \pi_{t+1}$ of a household with a **negative** model of inflation is:

- 47 b.p. $>$ those with neutral model
- 57 b.p. $>$ those with positive model

Microfounding endogenous α^i Back

Indirect utility:

$$\tilde{\mathbb{E}}_0^i \hat{U}_0^i = \frac{1-\beta}{(1-\beta\rho_y^i)^2} y_0 - \sigma\beta r_0 + \frac{1}{1-\beta\rho_\pi^i}\left(\frac{\beta\rho_\pi^i(\alpha^i+\lambda^i\phi^i)}{1-\beta\rho_y^i} - \sigma\beta^2\phi^i\rho_\pi^i + \frac{\partial c_t^i}{\partial\tilde{\mathbb{E}}_t^i\pi_t}\right)\tilde{\mathbb{E}}_0^i\pi_0$$
$$- \frac{\log(\bar{C}^i)}{2(1-\beta)}\left(\frac{\partial c_t^i}{\partial\tilde{\mathbb{E}}_t^i\pi_t}\right)^2 \frac{(1-K^i)\sigma_\pi^2}{1-(\rho_\pi^i)^2(1-K^i)}$$

Increasing in α^i iff:

$$\tilde{\mathbb{E}}_0^i\pi_0 > \frac{\log(\bar{C}^i)(1-K^i)\sigma_\pi^2}{(2-\beta)(1-(\rho_\pi^i)^2(1-K^i))}\cdot\frac{\partial c_t^i}{\partial\tilde{\mathbb{E}}_t^i\pi_t}$$

Therefore if household faces Knightian uncertainty about α^i, distort to worst case after forming $\tilde{\mathbb{E}}_0^i\pi_0$. High perceived $\pi \implies$ worst case is low α.

Information and perceived inflation Back

Model implications:

Negative subjective models:

- $\tilde{\mathbb{E}}_t^i \pi_t \uparrow \implies$ subjective model more negative.
- $\implies$ Corr (info, $\tilde{\mathbb{E}}_t^i \pi_t$) > 0

Positive subjective models:

- $\tilde{\mathbb{E}}_t^i \pi_t \uparrow \implies$ subjective model less positive.
- $\implies$ Corr (info, $\tilde{\mathbb{E}}_t^i \pi_t$) < 0

Table: Regression of perceived inflation on information by subjective model.

	$\tilde{\mathbb{E}}_t^i \pi_t$	$\tilde{\mathbb{E}}_t^i \pi_t$
Information	0.226**	-0.122
	(0.102)	(0.138)
Subj. model	Negative	Non-negative
HH controls	Yes	Yes
Time FE	Yes	Yes
Observations	5114	2787

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Implications Back

Selection:

- Attentive households are the ones who would react the strongest to information.
- Measures of average inattention **overstate** aggregate effects of info frictions.

Detail Implication for RCTs

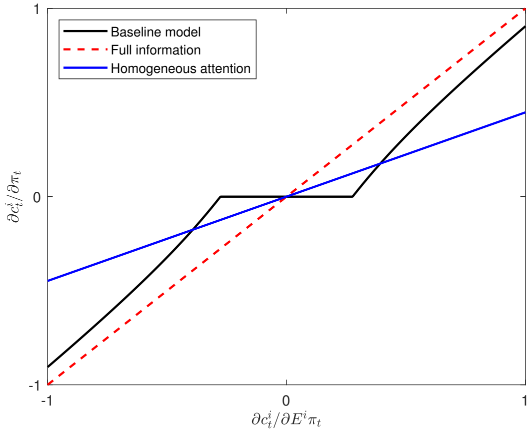
Size and history-dependent shock transmission:

- Large π_t increase $\implies$ more bias towards **negative** models of inflation.
- Effect persists through higher priors in $t + 1$.
- Largest effect on those somewhat aware of the inflation - i.e. with somewhat negative models.

Detail Quantification

Implication: selection in attention Back

Figure: Reaction to shock by subjective model

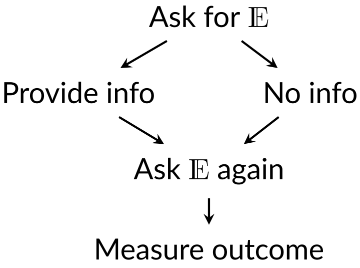


- The households who are attentive to inflation are the ones who would react strongest to information.
- Aggregate measures of inattention **overstate** aggregate effects of info. frictions.
- $\frac{dc_1}{d\pi_1}$ closer to FI benchmark than if all HHs have average information.

Micro: large inattention in data (Link et al, 2021)
Macro: need small inattention (Maćkowiak and Wiederholt, 2015)

Implications: selection in attention Back

Recent trend: survey RCTs to estimate causal effects of expectations.



Generate exogenous variation in $\mathbb{E}$ by instrumenting with $\mathbb{1}$(shown information).

- Estimates **local** effect on those who update the most.
- i.e. those who go in least informed, who have the lowest $dc/d\mathbb{E}\pi$.

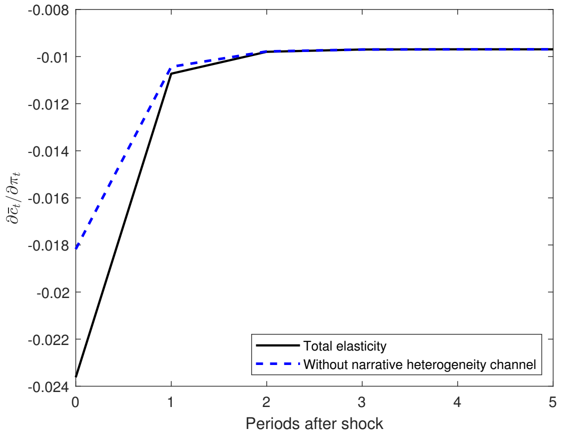
Is this the relevant group?

- Central bank communication: ✓
- Forward guidance/macro shocks: X

Implications: time-varying shock transmission Back

Figure: $\partial \bar{c}_t / \partial \pi_t$ after transitory 1% pt. π shock.

Calibration



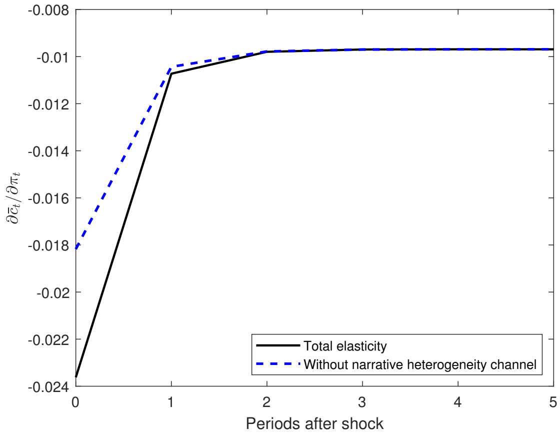
- High $\pi_t \implies$ high perceived π_t
- $\implies$ more bias towards **negative** models of inflation.

Implications: time-varying shock transmission

Back

Figure: $\partial \bar{c}_t / \partial \pi_t$ after transitory 1% pt. π shock.

Calibration



- High $\pi_t \implies$ high perceived π_t
- $\implies$ more bias towards **negative** models of inflation.
- Largest effect on those somewhat aware of the inflation - i.e. with somewhat negative models.
- $\implies$ **narrative het. channel** amplifies average effect.

Narrative heterogeneity accounts for **39%** of $s.d.\left(\frac{\partial \bar{c}_t}{\partial \pi_t}\right)$ Simulated elasticity time series

Quantifying the narrative heterogeneity channel for inflation Back

Calibrate model to UK: quarterly frequency. Normalise $\bar{C} = 1$.

Parameter	Value	Source	Parameter	Value	Source
β	0.99	standard	ρ_π	0.329	estimated subj. model
σ	1	standard	ρ_y	0.731	estimated subj. model
ϕ	β^{-1}	Lee et al (2013)	σ_π	0.003	estimated subj. model
$\bar{\alpha}^i$	-0.732	estimated subj. model	σ_r	0.004	estimated subj. model
λ	-0.037	estimated subj. model	σ_y	0.008	estimated subj. model

Choose remaining parameters to match average proportion on negative model, elasticity of that proportion to inflation, and average $\mathbb{E}_t^i \pi_t$ responsiveness to inflation shocks in IAS.
$s.d.(\alpha) = 0.613$, $\alpha_1^i = -234$, $\mu = 0.787 \times 10^{-9}$

$\implies$ narrative heterogeneity channel lowers steady state $dc/d\pi$ by **56%**, and accounts for **39%** of its standard deviation.