Learning Under Multiple Information Sets

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Seminar: National Bank of Ukraine

Motivation

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  - Use public information?
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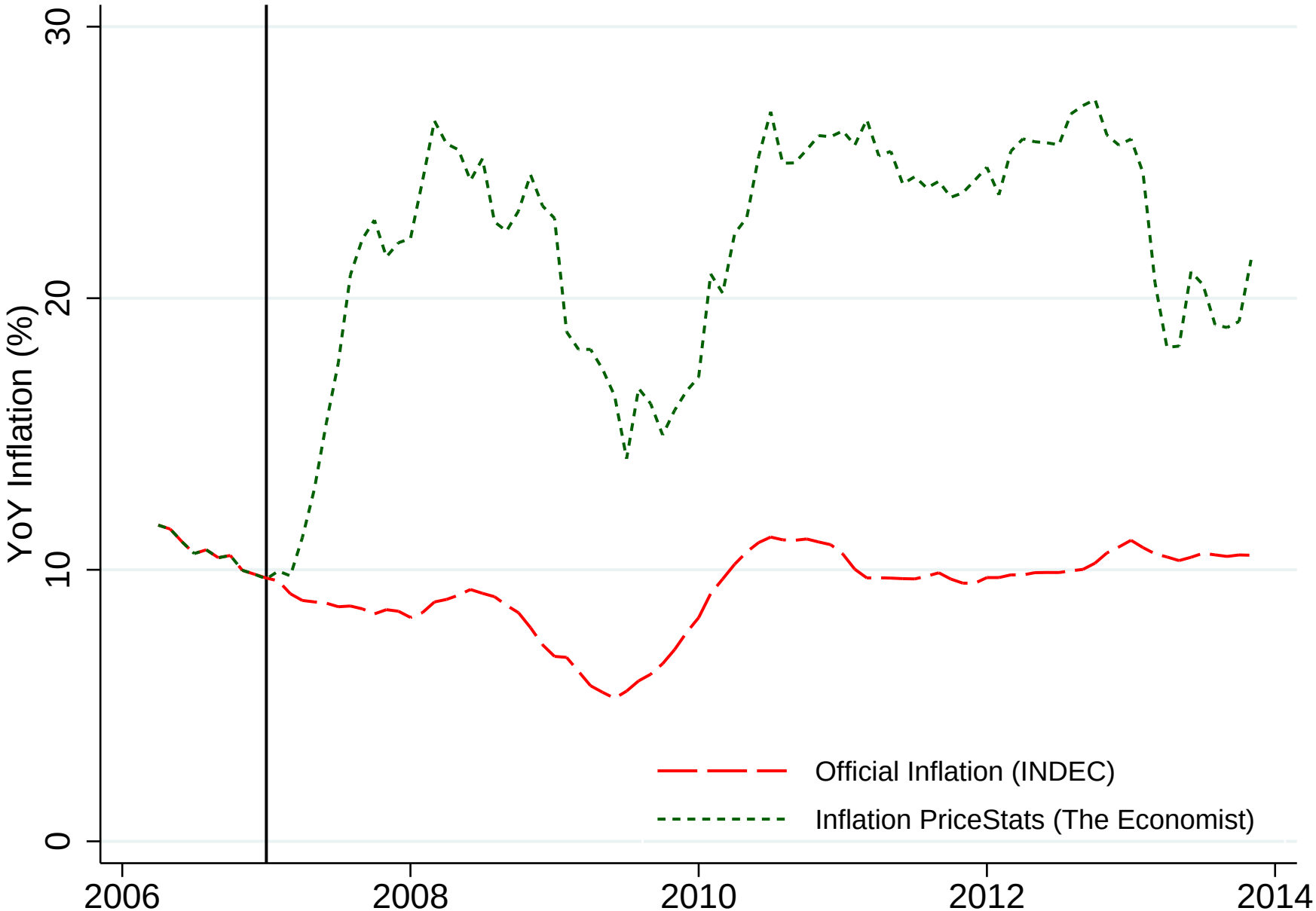
- Important for
  - Consumption/saving decisions
  - "Anchored" inflation expectations
- Yet, little evidence on the (not) use of **inflation experience**
  - Hard to observe inflation experience
  - Hard to separate from the use of public information

Argentina: days of multiple inflation statistics



Argentina: days of multiple inflation statistics

The Economist

Today Weekly edition Menu

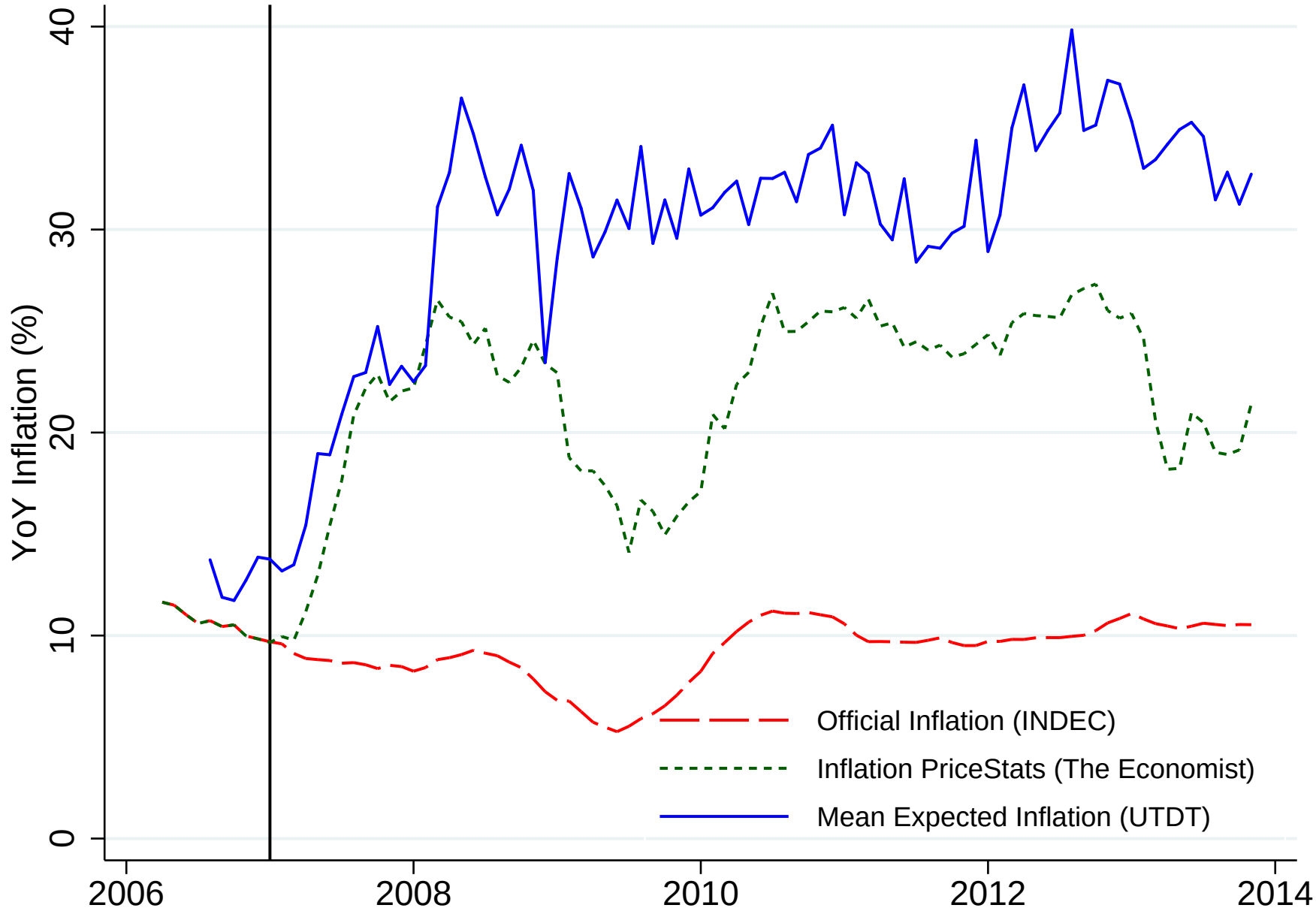
Leaders

Official statistics

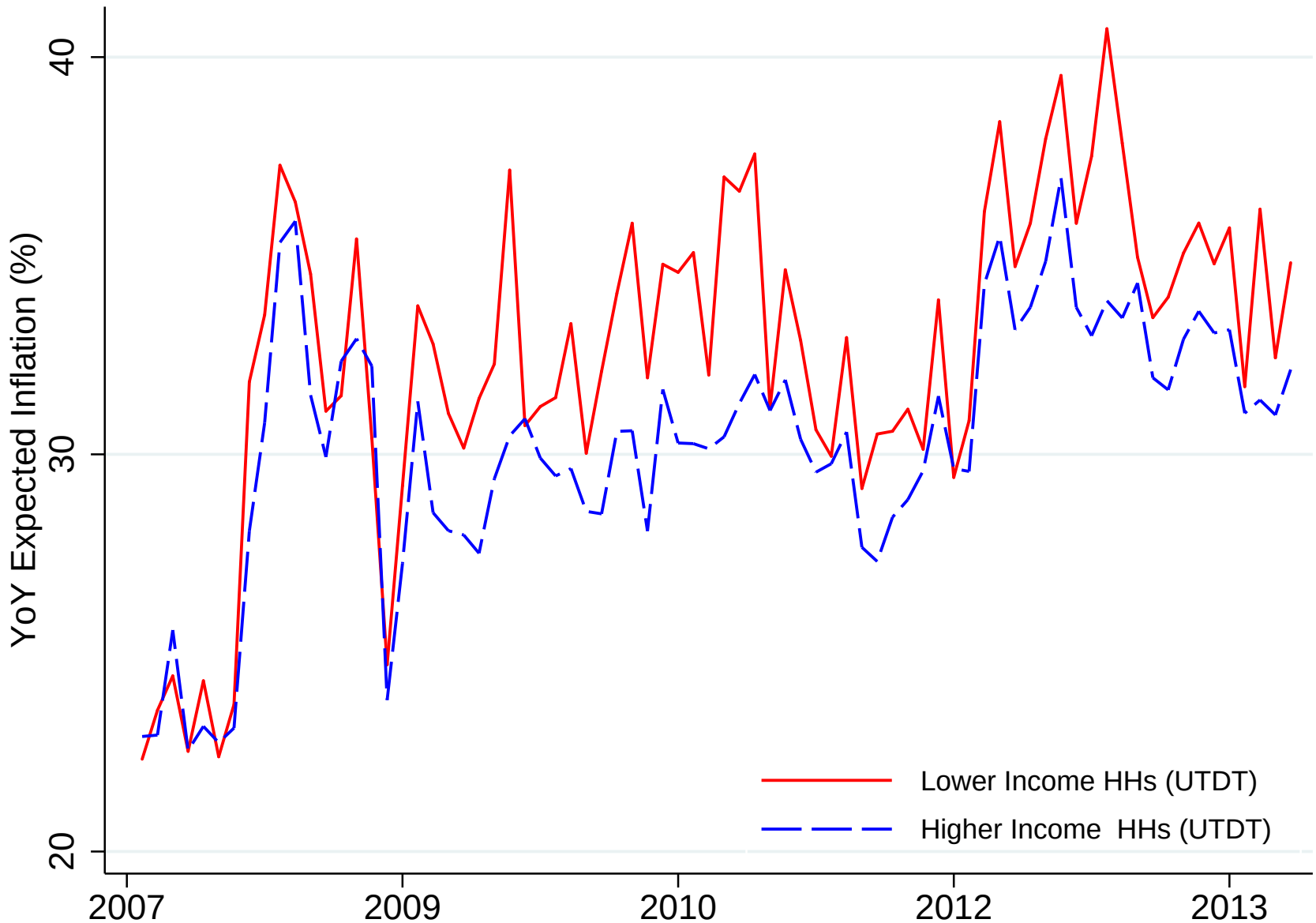
Don't lie to me, Argentina

Why we are removing a figure from our indicators page

Argentina: days of multiple inflation statistics



Deeper Look on Inflation Expectations



This Paper

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Under:

- Uncertainty about quality of public information (*multiple statistics*)
- Dispersion in relative prices (*moderately high inflation*)

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What I do:

Evidence

- Measure inflation experience: ("inflation") at household level
- Link *inflation experience* to *expectations* across income groups
- Analyse interaction with public information

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Theory

- Bayesian learning with (potentially) biased signals (public,idiosyncratic)
  - Different "persistent" inflation experiences
  - Low quality of public information (noisy and biased)

Contribution and preview of main results

This paper finds that (evidence):

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- HHs' **inflation experience** shape **inflation expectations**

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Contribution and preview of main results

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- HHs' **inflation experience** shape **inflation expectations**
- **Dispersion in relative prices** generates heterogeneity
- Explains **heterogeneity** of expectations **across income groups** (consume different bundles of goods)

when doubts about quality of public information

Literature: general Literature: specific

Contribution and preview of main results

This paper shows (theory):

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This paper shows (theory):

- Disentangle public *information uncertainty* from *price dispersion*
- To "anchored" expectations: see and believe in public information
- Believe in the sense that information is unbiased

Evidence

Inflation experience: household-specific inflation rate

- Laspeyres fixed-base quantity price indexes (benchmark)

$$CPI_t^h = \sum_j w_j^h I_t^j$$

product-categories $j = 1, ..., C$ and HH h

- CPI_t^h: consumer price index for household h
- I_t^j: product-category index j
- w_j^h: weight of product-category index j in household h CPI

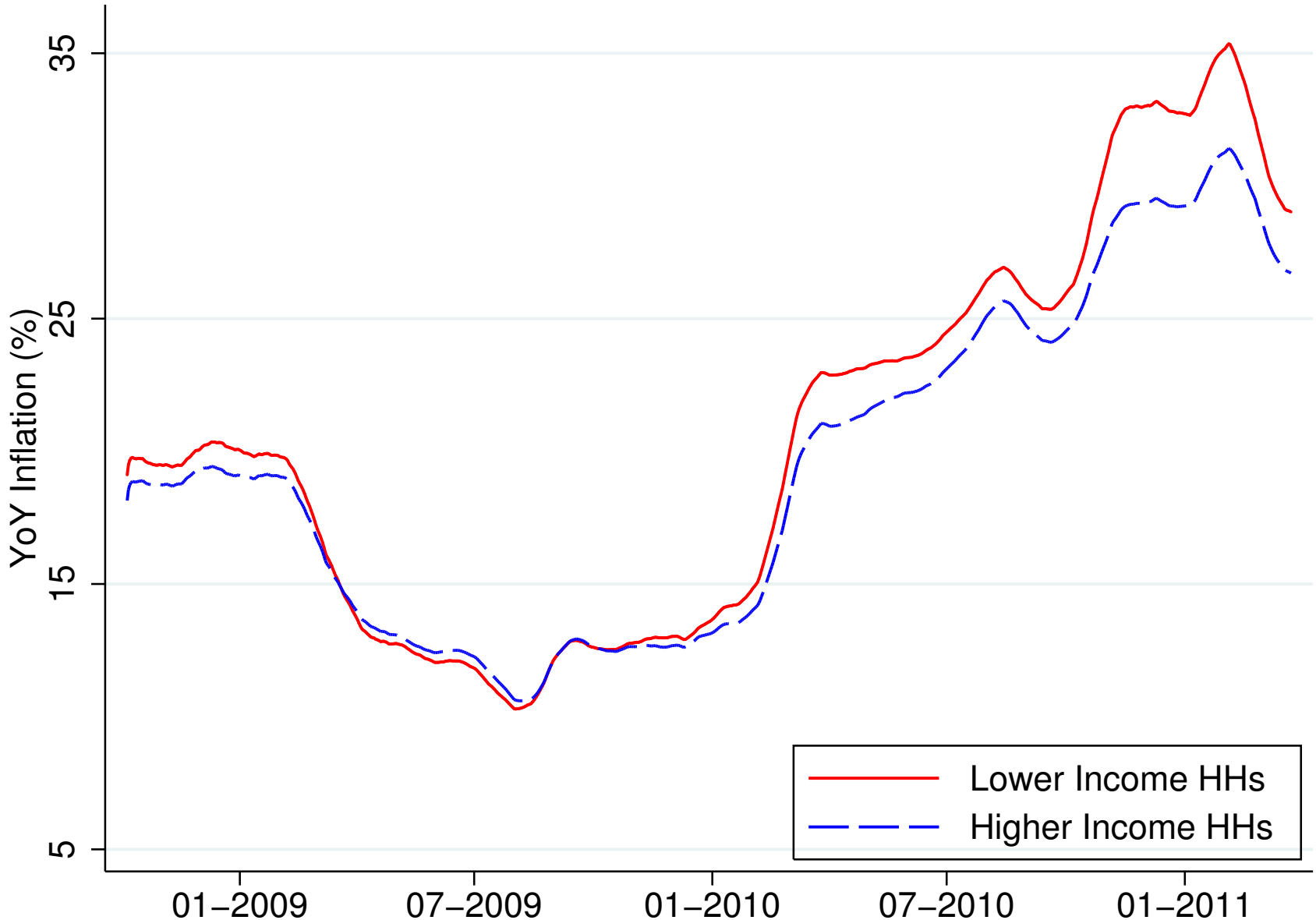
Details

Data

The case of Argentina

- Expenditure shares (CES ENGH 2004-2005)
  - Around 25.000 HHs
  - At least 5 product-categories
- Prices (The Billion Prices Project)
  - Micro Data on online prices for one retailer ("Walmart")
    - 20 million price quotes, more than 26,000 products
  - Market Share: 28% (online and "offline" market)
  - Daily: 10-2007 to 03-2011
  - Product-categories (BLS): 53 (48% of CPI)
- Inflation Expectations' Survey (UTDT)

Household-specific Inflation by Income



Inflation experience and expectations: *higher income HHs*

	$\pi^{Expectations(HI)}_{t+12\|t}$		
$\pi^{Official\ (public)}_{t-1}$	-0.640**	-1.515**	-1.392**
	(0.304)	(0.652)	(0.617)
$\pi^{The\ Economist\ (public)}_{t-1}$	0.958***	0.230	0.158
	(0.0809)	(0.237)	(0.249)
$\pi^{\textbf{Experienced (HI)}}_{t-1}$		0.548***	0.570***
		(0.138)	(0.140)
$\pi^{Experienced\ (HI)}_{t-2}$		-0.0537	-0.0706
		(0.151)	(0.137)
$\pi^{Expectations(HI)}_{t+11\|t-1}$			-0.166
			(0.137)
Constant	14.18***	21.09***	26.63***
	(2.581)	(3.923)	(5.355)
Trend	NO	YES	YES
Observations	90	29	29

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

Inflation experience and expectations: *lower income HHs*

	$\pi^{Expectations(LI)}_{t+12\|t}$		
$\pi^{Official\ (public)}_{t-1}$	-0.773*	-1.067	-1.117
	(0.401)	(1.053)	(1.060)
$\pi^{The\ Economist\ (public)}_{t-1}$	1.138***	0.0485	0.0431
	(0.0989)	(0.384)	(0.392)
$\pi^{Experienced\ (LI)}_{t-1}$		0.588*	0.611*
		(0.303)	(0.299)
$\pi^{Experienced\ (LI)}_{t-2}$		-0.0192	-0.000935
		(0.299)	(0.318)
$\pi^{Expectations(LI)}_{t+11\|t-1}$			-0.107
			(0.179)
Constant	13.48***	22.16***	24.79***
	(3.709)	(7.178)	(7.300)
Trend	NO	YES	YES
Observations	90	29	29

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Relative Prices

- Now, two group-specific CPIs: lower and higher income (reference)
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			Lower-Income CPI	
Product-Category (Selected)	Price Change (PC)	Relative PC	Relative Weight	Impact (p.p)
Uncooked Beef Steaks	219.6%	+67%	+57%	2.87
Bread	107.1%	+8%	+59%	0.25
Pasta	104.5%	+7%	+15%	0.03
Chicken	103.3%	+6%	+54%	0.09
Higher-Income CPI	91.4%			
Books	31.8%	-31%	-49%	0.28
Home Furniture	28.6%	-33%	-31%	0.22
Appliances	28.2%	-33%	-43%	0.46
Total				4.30

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- Food Prices: faster increase + more weight in lower income HHs

Details

Inflation experience and expectations

- What explains different inflation experiences?
  - Relative Prices

- What happens with?
  - Substitution Effect Go
  - Other well known public signals Go
  - Different prices

- Link to expectations: what remains to be explained?
  - Uncertainty of public information vs. relative price dispersion
  - Overshooting of expectations Go Go2
  - Use of both public and idiosyncratic information
    - Negative sign in official inflation

A (potentially) biased-information model

Bayesian Learning Model

- Households form expectations about inflation
- **Multiple sources of information**
  - Public and idiosyncratic ("inflation experience") signals
- **Household types**
  - Observe same public signal
  - Have their own inflation experience
- Public and idiosyncratic **information (potentially) biased**
  - Public biased signals (Cavallo et al, 2016)
  - Different "persistent" inflation experiences

Bayesian Learning Model

Inflation Environment

- Household-specific inflation (for simplicity normal)

$$\pi_t^i \sim \mathcal{N}(\mu_i, \sigma_i^2)$$

Bayesian Learning Model

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- Inflation rate in the economy (N households)

$$\pi_t = \sum_{i=1}^{N} \alpha_i \pi^i$$

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follows

$$\pi_t \sim \mathcal{N}(\mu, \sigma^2),$$

with $\mu \equiv \sum_{i=1}^{N} \alpha_i \mu^i$, $\sigma^2 \equiv \sum_{i=1}^{N} \alpha_i^2 \sigma_i^2$

Bayesian Learning Model

Inflation Environment: different "persistent" inflation experiences

- Difference between household-specific inflation i and inflation rate

$$b_t^i \equiv \pi_t^i - \pi_t$$

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$$b_t^i \equiv \pi_t^i - \pi_t$$

- Idiosyncratic bias

$$E(b_t^i) = \mu_i - \mu$$

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$$b_t^i \equiv \pi_t^i - \pi_t$$

- Idiosyncratic bias

$$E(b_t^i) = \mu_i - \mu$$

- Different "persistent" inflation experiences if $E(b_t^i) \neq 0$

Bayesian Learning Model

Inflation Signals

- Households objective is to learn Inflation: $E(\pi_t)$

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Household-specific inflation: implicit signal of overall inflation

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- Public noisy signal

$$\pi_t^p = \pi_t, \qquad \pi_t \sim \left(\mu, \sigma^2\right)$$

- Public knowledge of σ^2 and σ_i^2

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Bayesian Learning Model

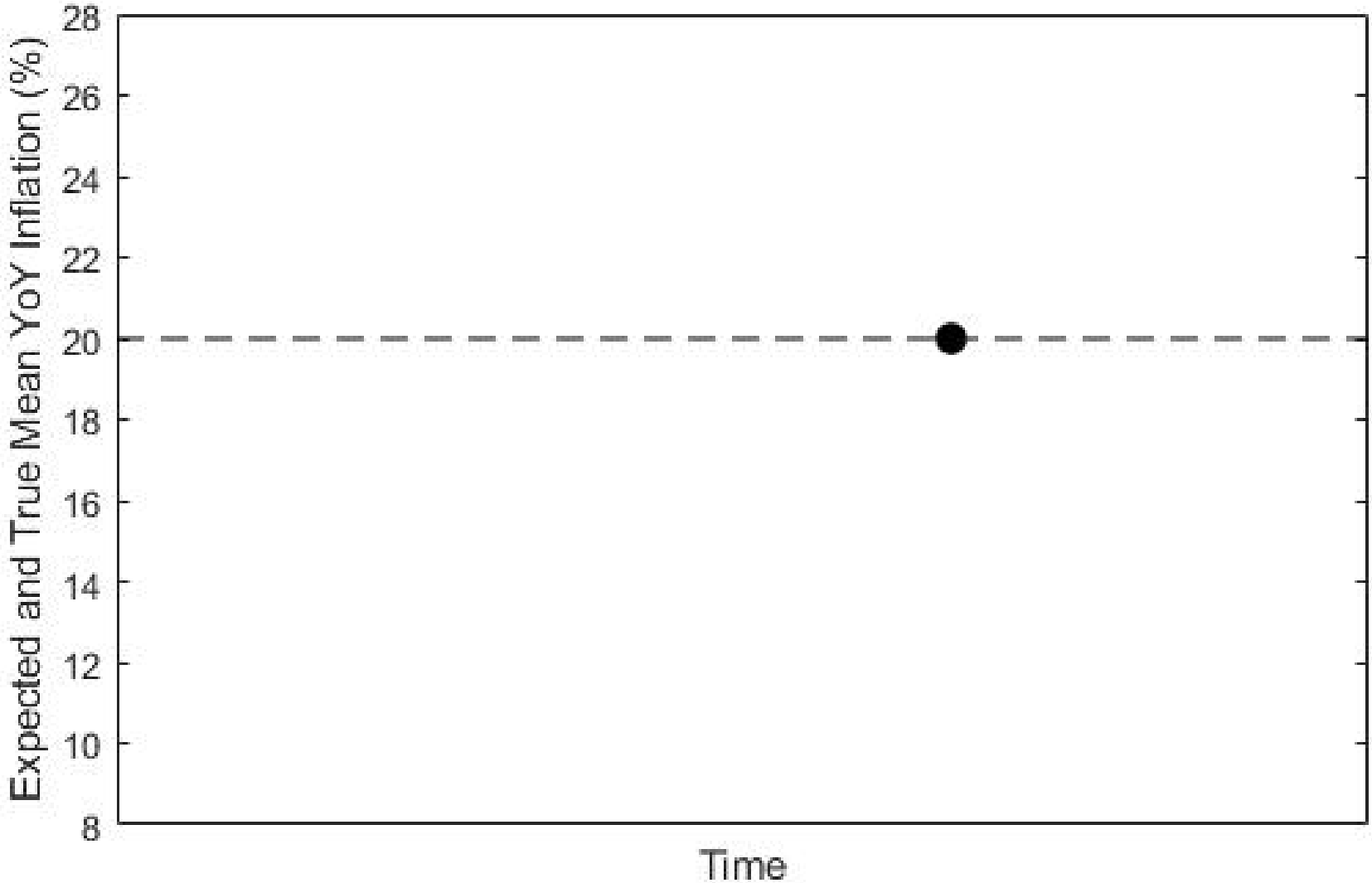
Inflation Expectations

- Assume normal and orthogonal initial prior
- Inflation expectations

$$
\begin{aligned}
E[\pi^{e,i}_{t+1|t}|\mathcal{I}^i_t] = \pi^{e,i}_{t|t-1}(1-\psi_1-\psi_2) \\
+ (\pi^{p}_{t|t} - b^{p}_{t|t-1})\psi_1 \\
+ (\pi^{i}_{t|t} - b^{i}_{t|t-1})\psi_2
\end{aligned}
$$

where $\mathcal{I}^i_t = \{\pi^p_s, \pi^i_s : s = 1, .., t\}$ Bias Theorem

Intuition


Expected and True Mean YoY Inflation (%)
28
26
24
22
20
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16
14
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Time

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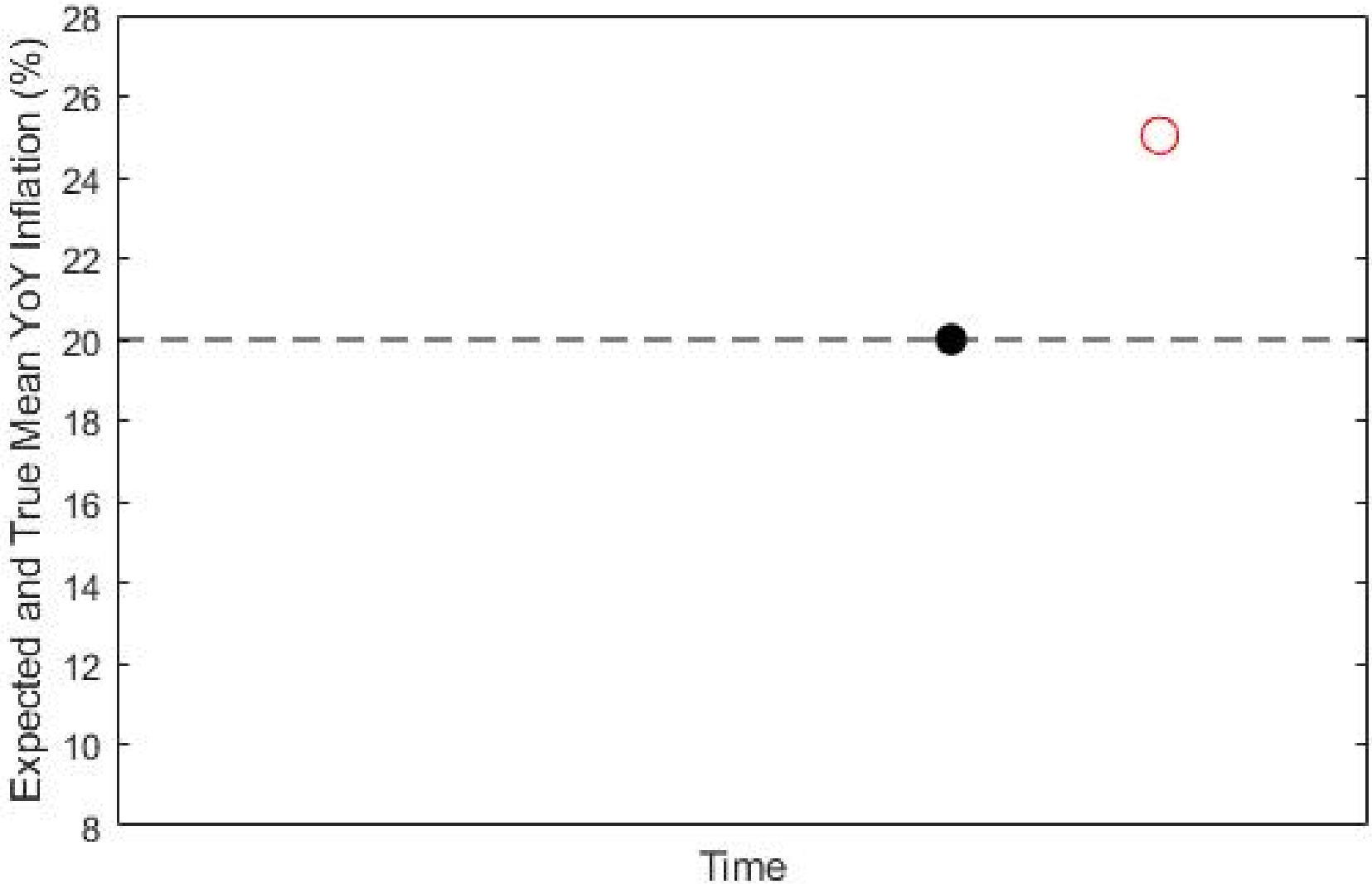
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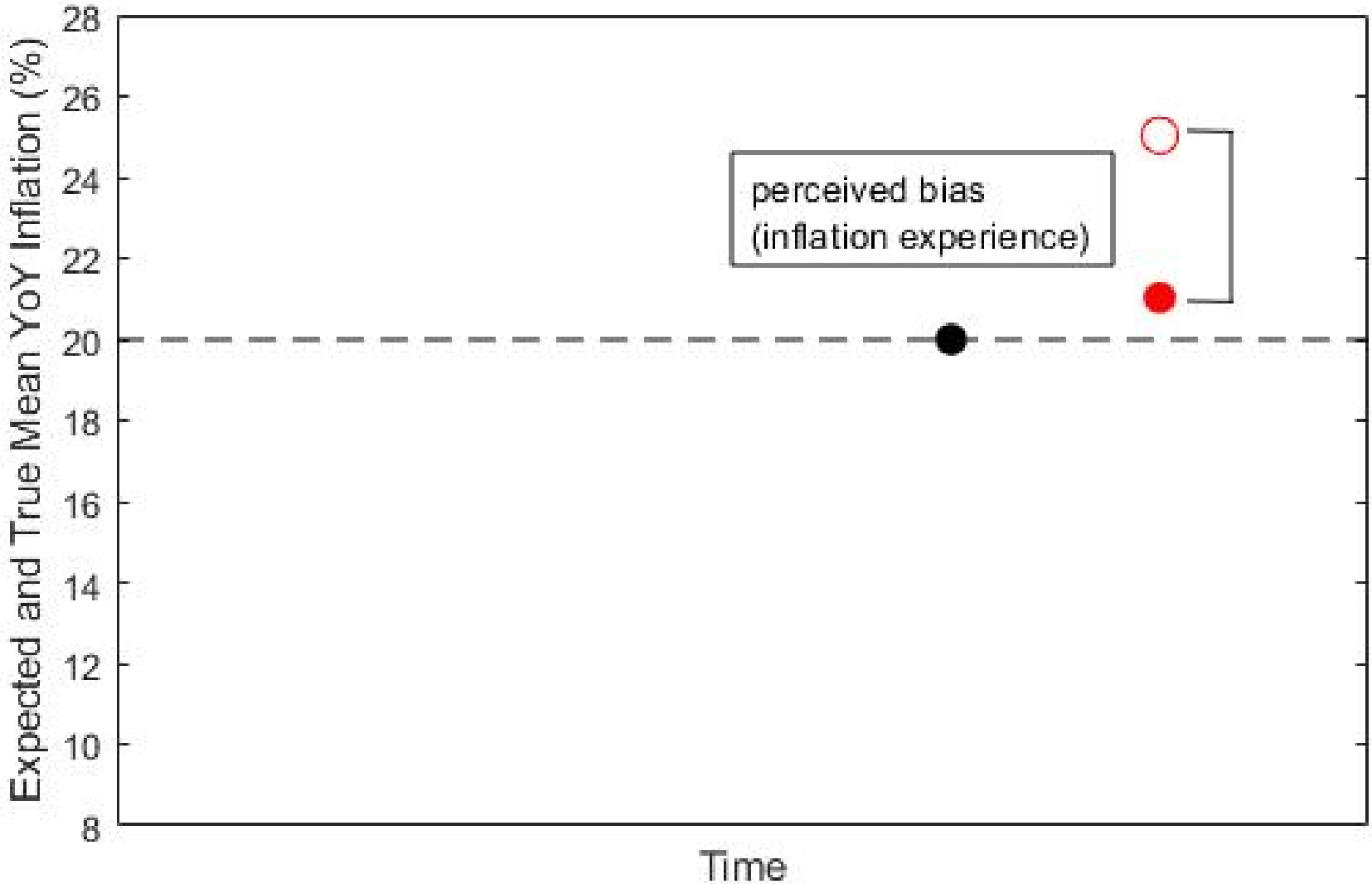
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Expected and True Mean YoY Inflation (%)
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perceived bias
(inflation experience)

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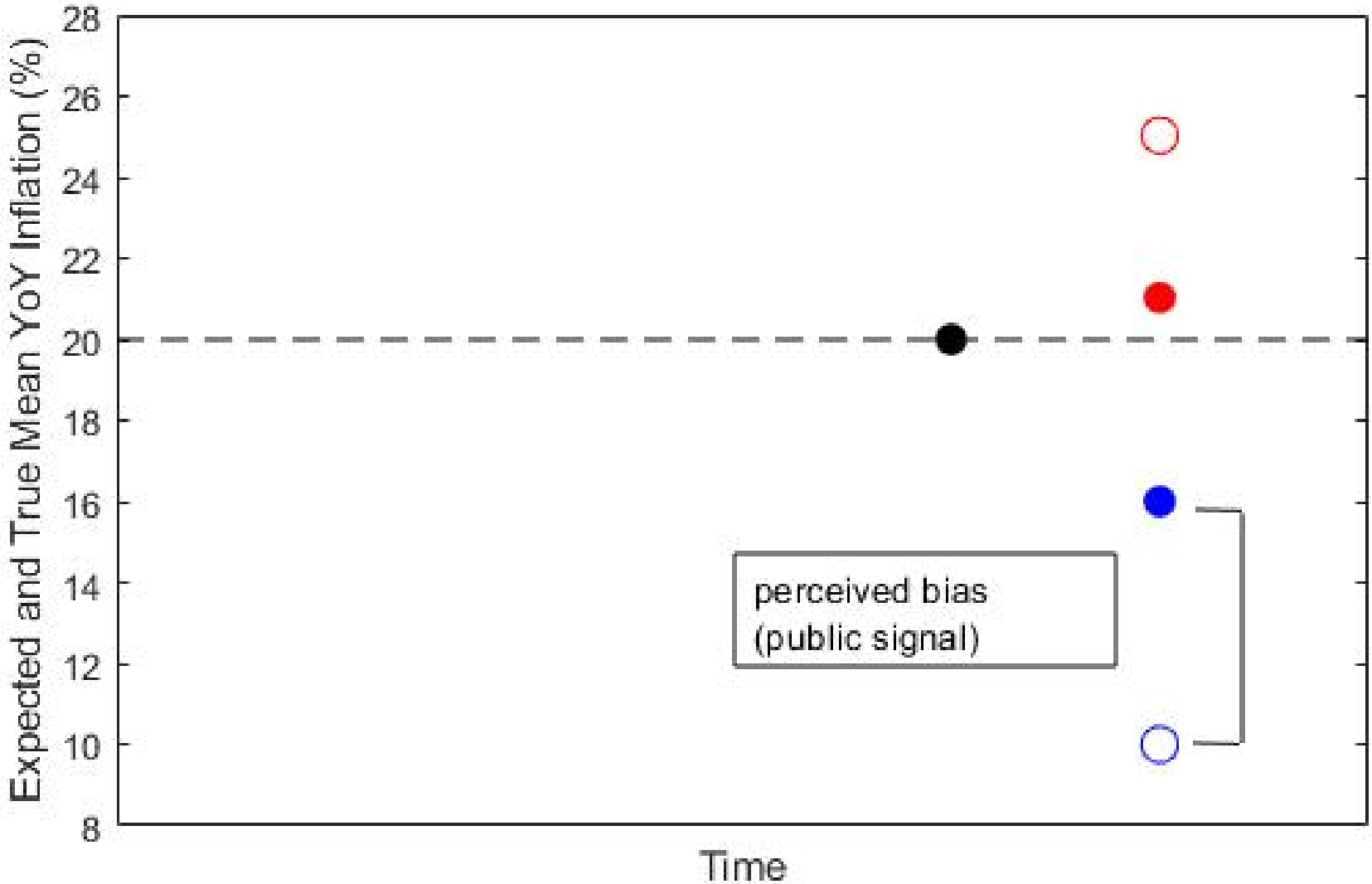
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Time
perceived bias
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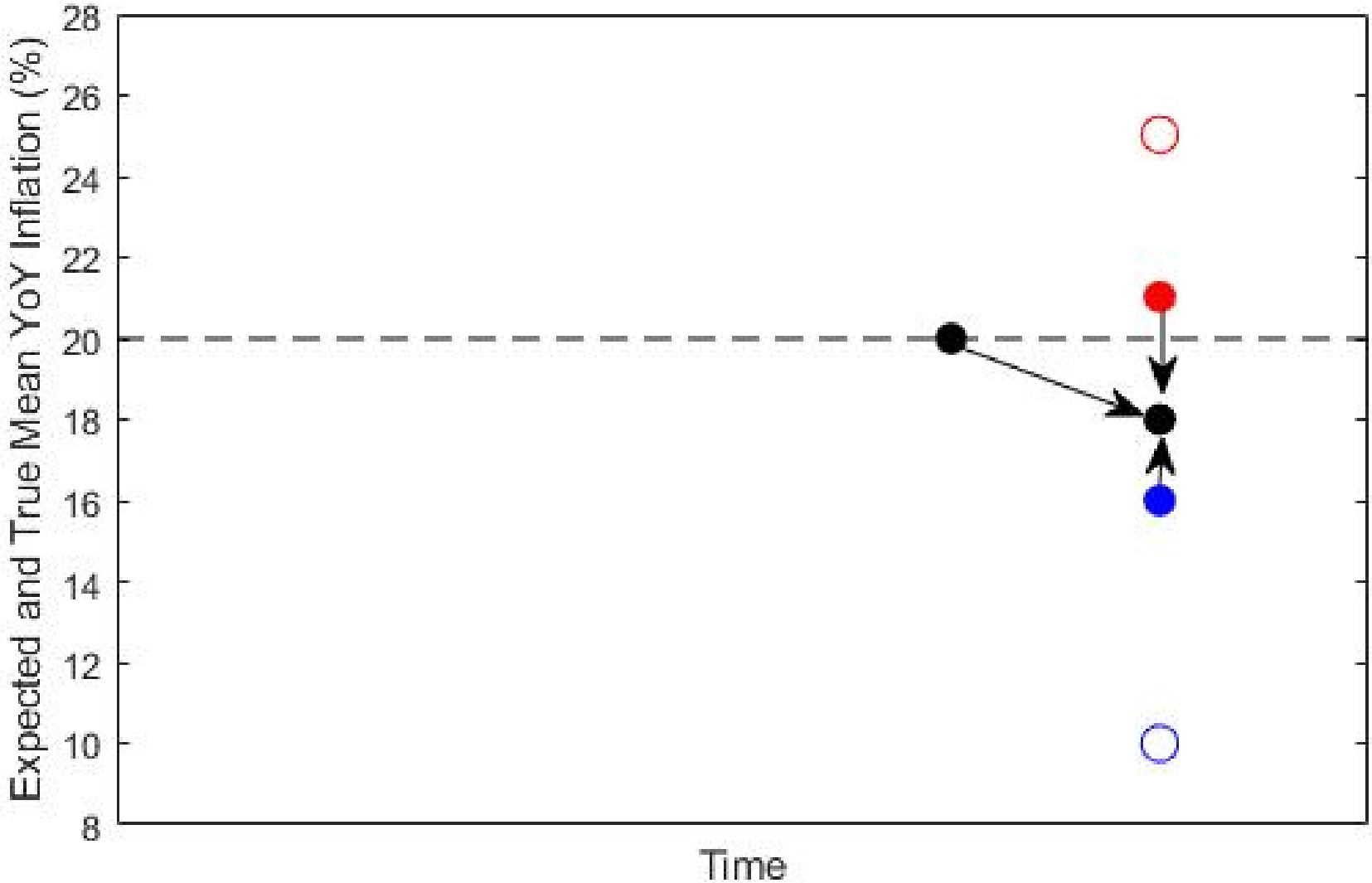
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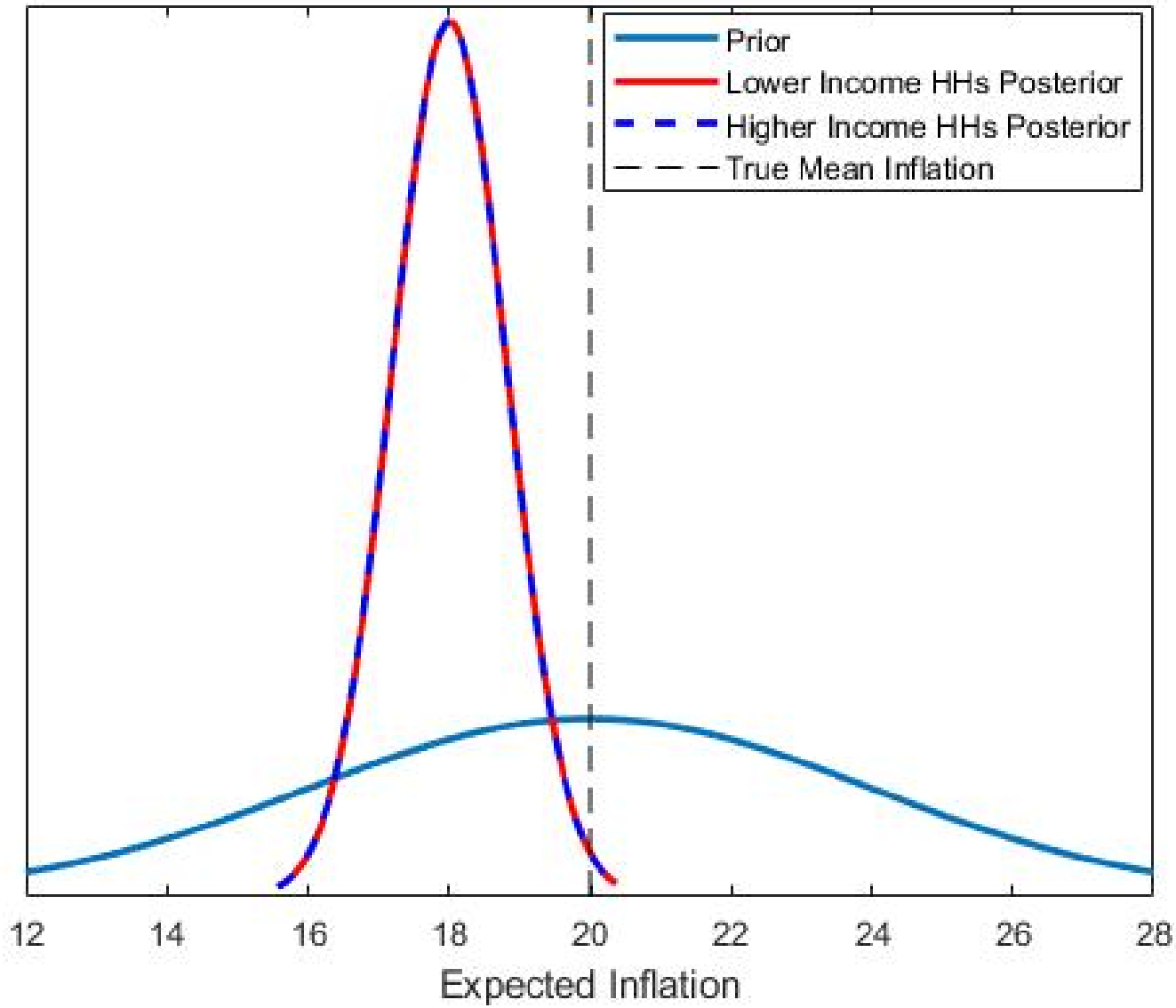
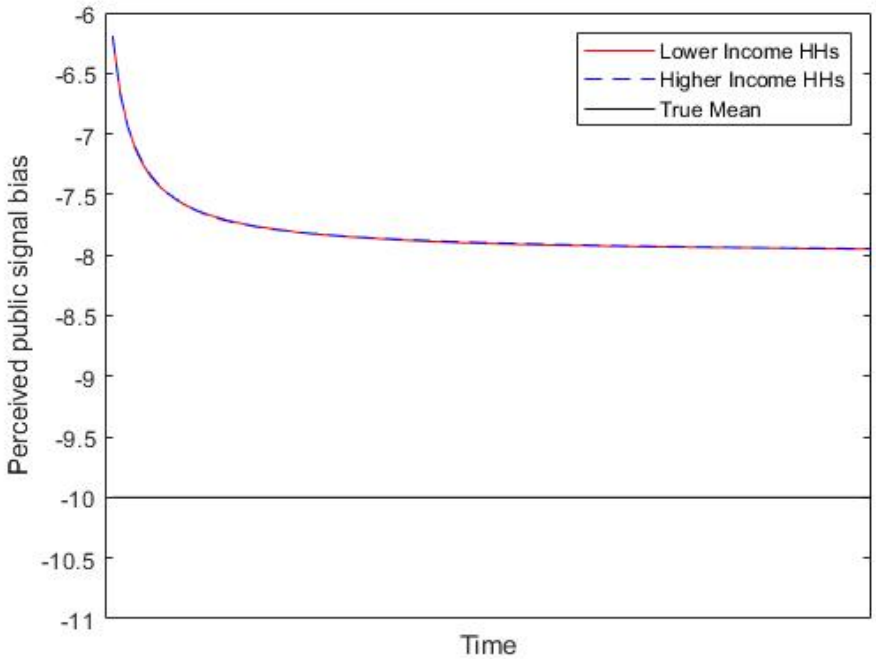
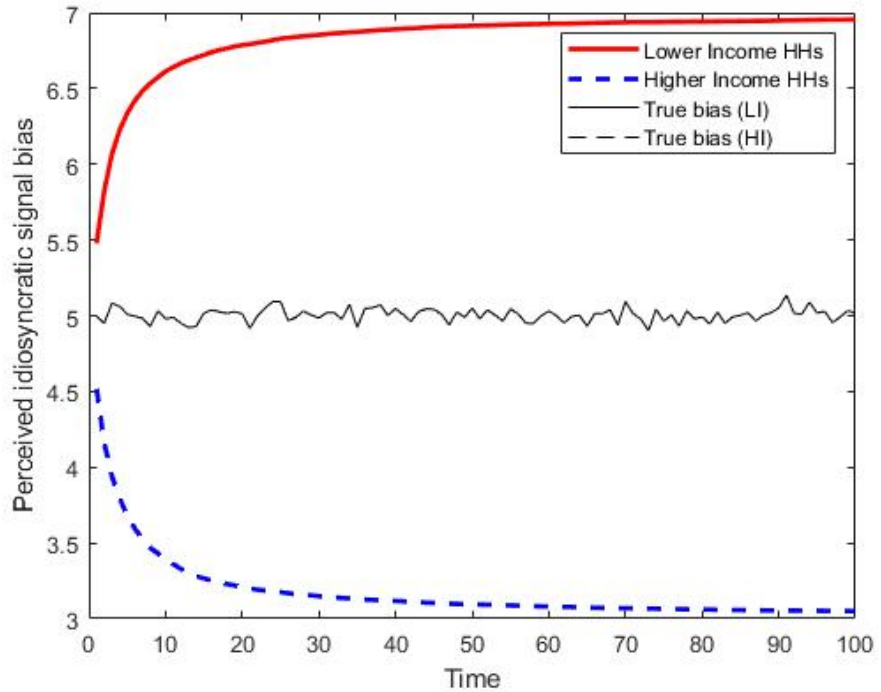
Households fall short in the downward bias of government



Households fall short in the downward bias of government

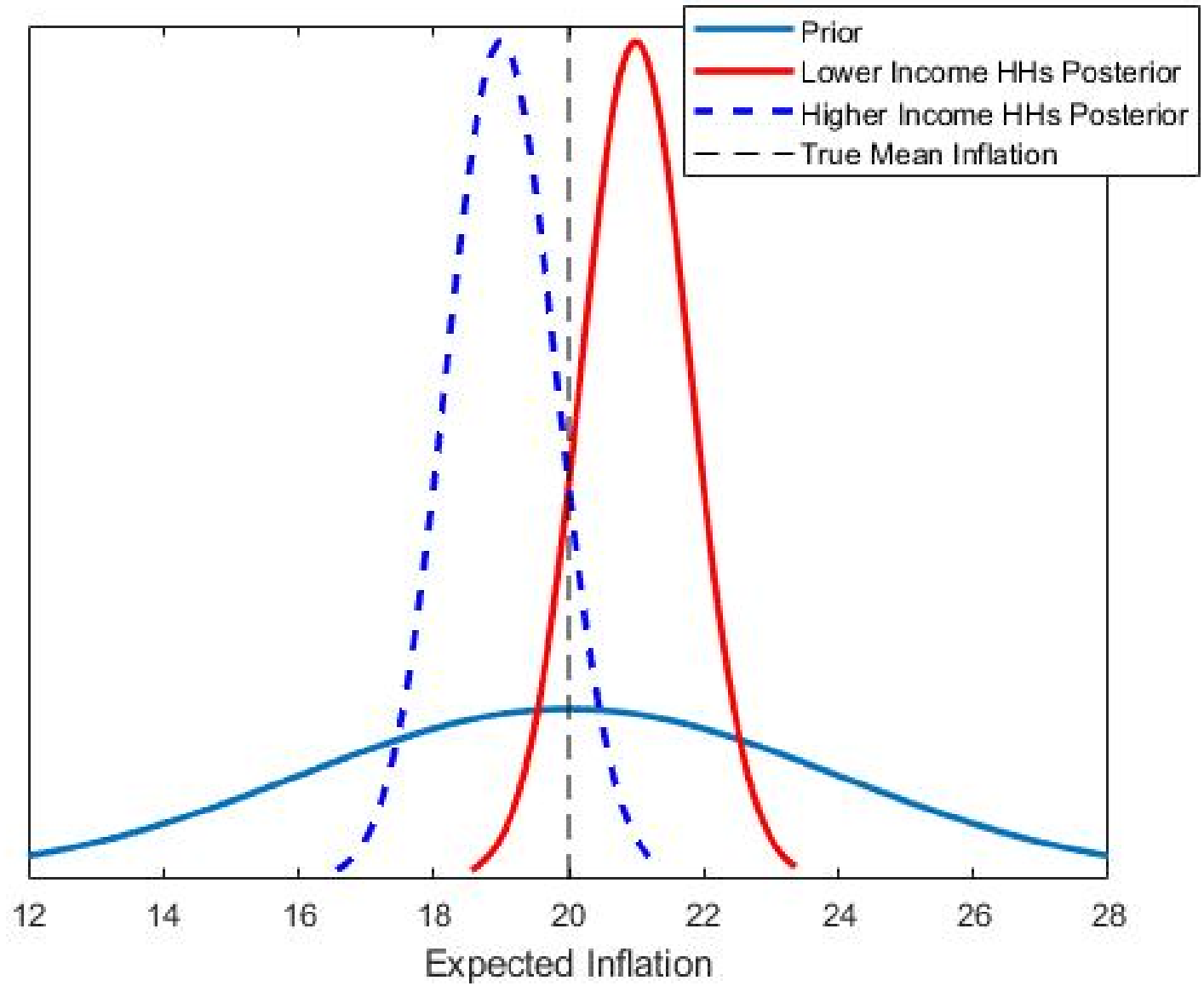
Expectations about government and idiosyncratic bias





- True targets $[\pi \quad b^p \quad b^i] = [20 \quad -10 \quad \pm 5\,]$
- Priors-Data $[\pi_0 \quad b_0^p \quad b_0^i; \quad \pi^p \quad \pi^i] = [20 \quad -5 \quad \pm 5\,; \quad 10 \quad 25/15]$

Effect of inflation experience on expectations



Households are overconfident in their own inflation experience

Effect of inflation experience on expectations

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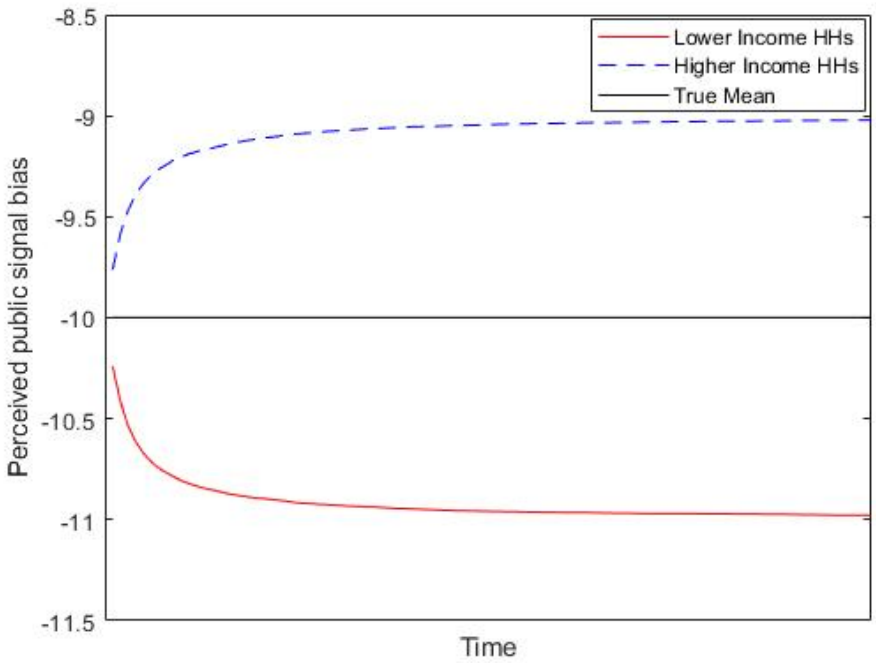

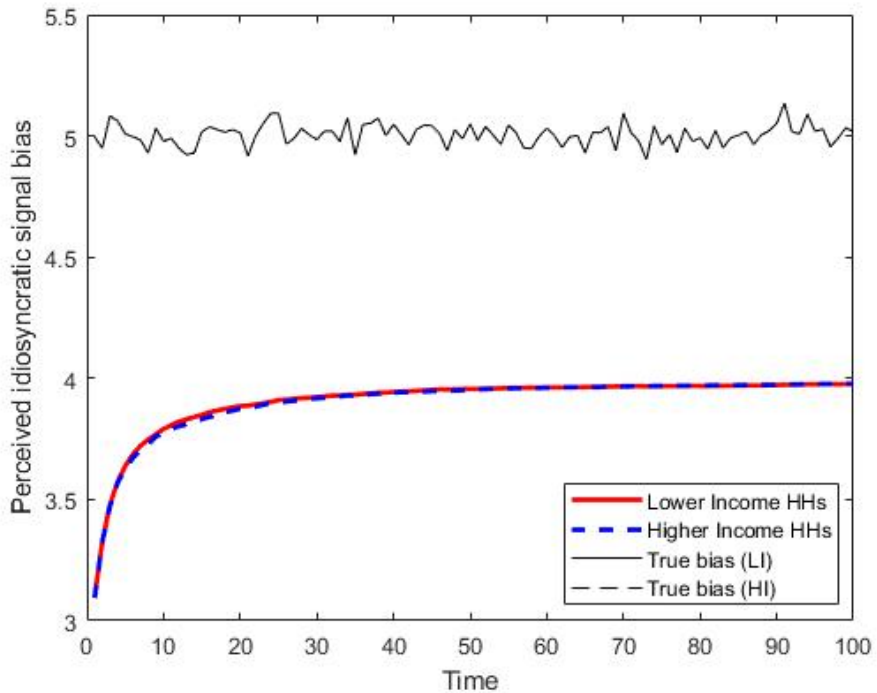

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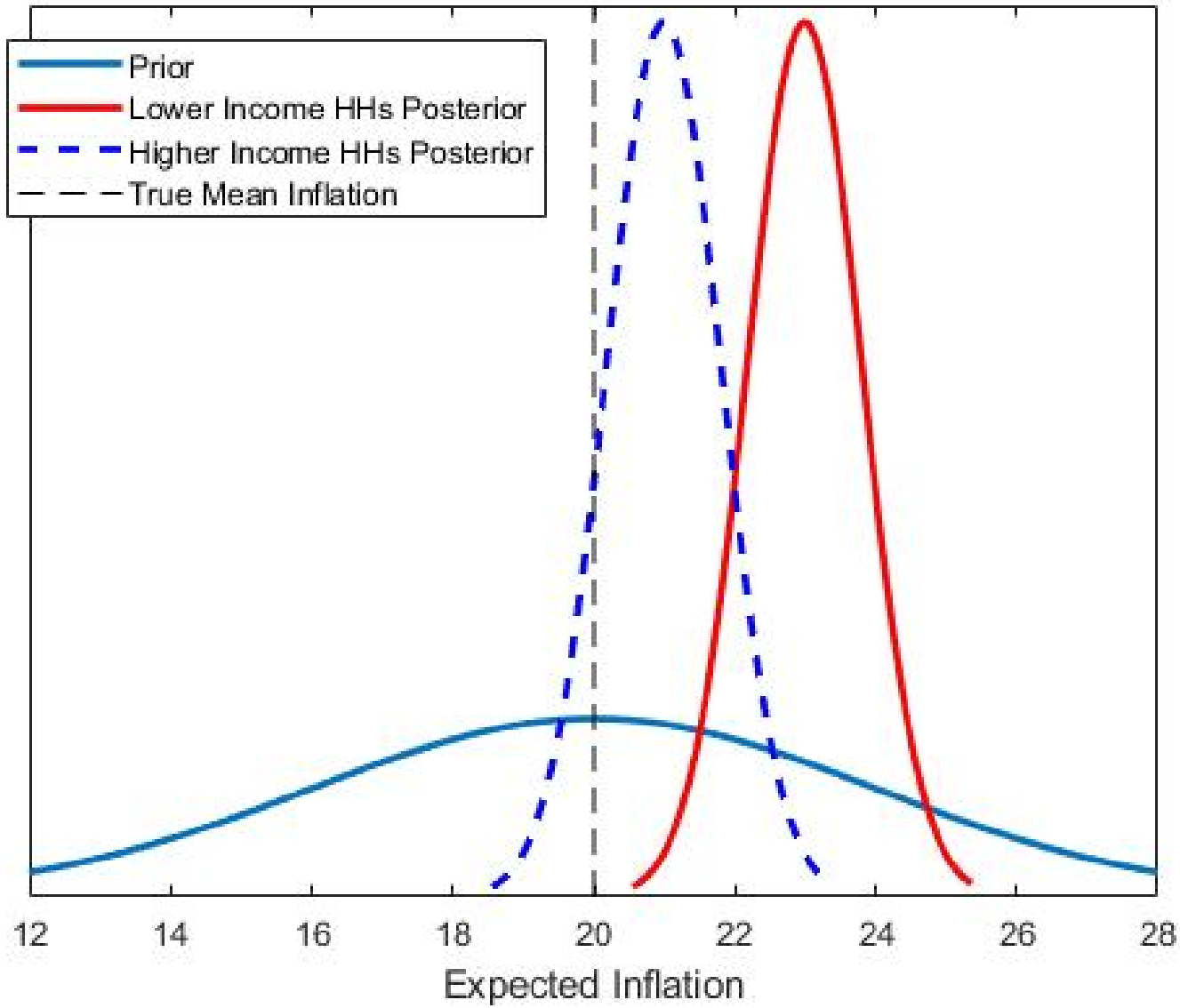
Effect of inflation experience and "fear" of government bias



Negative sign

Inflation experience and expectations

Other things to be considered

- Substitution Effect Go
- Other well known public signals Go
- Different prices
  - More price dispersion across categories than within categories
- Difference in sophistication
  - Less important in moderately high-inflation environments
- "Normal times": US late 70's and early 80's
- Households track their own household-specific inflation
  - General problem of surveys
  - Contracts
  - Overshooting of expectations and no prediction
  - Right "wording".

Conclusions

I provide evidence of:

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  (when there are doubts about the quality of public information)

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I show (theory):

- **Uncertainty in quality of public information**
  - may affect learning and agreement
  - due to existence of (potentially) biased public information

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Policy implications: Go

- **Anchoring** inflation expectations may be harder than we thought
  - Clarity and visibility of public information is essential

Policy

Policy implications (theory):

- **Anchoring** inflation expectations may be harder than we thought
  - Clarity and visibility of public information is essential

Policy implications (evidence):

- In low inflation environments people may be using their own inflation experience (D'acunto et al, 2019)
- Joint effort (statistics agencies and central banks) to anchored inflation expectations.

Inflation Expectations

General literature

- Behavioral Explanations
  - Behavioral Biases (Malmendier & Nagel, 2016)
- "Quasi-rational"
  - Adaptive Learning (Marcet & Nicolini, 2003)
  - Ambiguity uncertainty (Rezza Baqaee, 2019)
- Rational Explanations
  - REH (with expectations, not about expectations)
  - RE with Information frictions
    - Sticky-information (Mankiw & Reis, 2002)
    - Noisy-information, learning (Sims, 2003) (Woodford, 2003)
    - Bias-information, learning (Cavallo et al, 2016)

Back

Inflation Expectations and Experience

Literature of individuals using their own information on prices

- Perceptions and expectations (Jonung, 1981)
- Inflation experience during lifetime (Malmendier & Nagel, 2016)
  - Across cohort effects
- Dispersion within demographic groups (Johannsen, 2014)
- Inflation experience of change in prices of the goods purchased

  Low inflation environments:
  - D'Acunto et al (2019): frequency and size of prices changes (FS)
  - Angelico & Di Giacomo (2019): FS for differences across income
  - Madeira & Zafar (2015): expenditure shares

  High inflation environments:
  - Cavallo et al (2017): limitations to remember prices

My paper: Back

- expenditure shares rather than frequency and size of price changes
- "rational" response to the lack of reliable public information.

Inflation experience: household-specific inflation

- **Weights** (Consumer Expenditure Survey)

$$w_j^i = \frac{E_j^i}{\sum_{j=1}^{S} E_j^i} \quad with \quad \sum_{j=1}^{S} w_j^i = 1$$

  product-categories $j = 1, ..., S$ and HH i

- **Prices** (Web scraping)

  day-category unweighted geometric mean of relative prices (Cavallo, 2013) Details

- HH price index: weighted arithmetic mean of all categories

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- **Prices** (Web scraping)

day-category unweighted geometric mean of relative prices (Cavallo, 2013)

$$UGM_t^j = \prod_g (p_{t+1}^g / p_t^g)^{1/n_t^j}$$

  - compute category index j at t: $I_t^j = UGM_0^j . UGM_1^j ... UGM_{t-1}^j$

- HH price index: weighted arithmetic mean of all categories I_t^j

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Relative Prices

Relative Discrepancy by Income CPIs

$$RD = \left(\frac{I_t^j}{CPI_t^{HI}} - 1 \right) \left(\frac{w_j^{LI}}{w_j^{HI}} - 1 \right) \left(w_j^{HI} * 100 \right)$$

- I_t^j: product-category index j
- CPI_t^{HI}: consumer price index for higher income households
- w_j^{LI}: weight of product-category index j in lower-income CPI
- w_j^{LHI}: weight of product-category index j in higher-income CPI

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Substitution effect

- Lloyd–Moulton (CES)

$$CES - CPI_t^h = \left[\sum_j w_j^h (I_t^j)^{1-\sigma^i} \right]^{1/1-\sigma^i}$$

product-categories $j = 1, ..., C$, HH h and income group i

Substitution Elasticities Results Back Back Conclusions

Substitution Effect

- Households' expenditure shares by income and product-category price changes during consumer survey (Q4-2004 and Q4-2005)

Product-category	Price Change (%)	Expenditure shares (%)		Diff.(p.p.)
		Q4 2004	Q4 2005	
Lower income				
Uncooked Beef Steaks	24.8	12.0	11.2	-0.8
Bread	8.7	8.4	7.3	-1.1
Pasta	7.1	3.2	3.4	0.2
Chicken	6.3	4.7	3.8	-0.9
Higher Income				
Uncooked Beef Steaks	24.8	8.3	6.9	-1.4
Bread	8.7	5.5	4.4	-1.1
Pasta	7.1	2.6	3.1	0.5
Chicken	6.3	3.4	2.3	-1.1

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Substitution Effect

Estimates for the elasticity of substitution

- Estimate elasticities in two ways:
  - Reduced-form (Feenstra-Reinsdorf) Details FR
  - Using implicit substitution through the consumer survey ("Optimal" v.s. Tornqvist Index) Details Optimal

		"Optimal"	
	Feenstra-Reinsdorf	Quarterly	Annual
Higher Income HHs	0.97	1.27	1.03
Lower Income HHs	0.75	1.27	1.25

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Substitution Effect

- Feenstra et al (2007) and the BLS.

$$\Delta \ln w^i_{j,t} = -\alpha^i + \beta^i \Delta \ln p_{j,t} + \epsilon_{j,t}$$

  $\epsilon_{j,t}$ is an error term that captures change in tastes

- α^i and β^i estimated by a weighted OLS

$$\text{OLS-weight}^i_{j,t} = \frac{(w^i_{j,t} - w^i_{j,t-1})/(\ln w^i_{j,t} - \ln w^i_{j,t-1})}{\sum_{j=1}^{C}(w^i_{j,t} - w^i_{j,t-1})/(\ln w^i_{j,t} - \ln w^i_{j,t-1})}$$

- Eestimated elasticities of substitutions

$$\hat{\sigma}^i = 1 - \hat{\beta}^i$$

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Substitution Effect

- Optimal vs. Törnqvist Index

$$T - CPI_t^i = \prod_j \left(\frac{I_t^j}{I_{t-1}^j} \right)^{\frac{1}{2}\left(w_{j,t}^i + w_{j,t-1}^i\right)}$$

- Compare with a set of CES price indexes
- Elasticities starting at 0.01 and incremented by 0.01.
- Estimated elasticities of substitutions

$$\hat{\sigma}^i = \min_{\sigma} |CES - CPI_t^i \quad - \quad T - CPI_t^i|$$

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Substitution effect

Inflation experience and expectations

	Inflation expectations ($\pi^{Expectations}_{t+12|t}$)			
	Laspeyres	*CES (Reduced-form)*	*CES (Quarterly Optimal)*	*CES (Annually Optimal)*
$\pi^{Experienced\ (HI)}_{t-1}$	0.570***	0.607***	0.614***	0.605***
	(0.140)	(0.155)	(0.159)	(0.154)
$\pi^{Experienced\ (LI)}_{t-1}$	0.611*	0.736**	0.738**	0.687*
	(0.299)	(0.282)	(0.282)	(0.290)
Public Signals	YES	YES	YES	YES
Previous Expectations	YES	YES	YES	YES
Constant	YES	YES	YES	YES
Trend	YES	YES	YES	YES
Observations	29	29	29	29

Standard errors in parentheses

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

Back Group-specific inflation rates

Substitution Effect

Inflation experience: average household-specific inflation rates by income

	Laspeyres (%)	CES-FR (%)	CES-QO (%)	CES-AO (%)
Lower-Income				
Mean	20.45	19.96	19.95	20.15
Stand.Dev.	(2.48)	(2.47)	(2.47)	(2.47)
Cumulative	99.47	94.27	94.19	96.25
Higher-Income				
Mean	19.33	18.95	18.87	18.98
Stand.Dev.	(2.61)	(2.64)	(2.65)	(2.64)
Cumulative	91.23	87.80	87.05	87.98

Notes: All difference in means are statistically significant at 1%.

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Bayesian Learning Model

Bias updating

$$
\begin{aligned}
E[b^g_{t+1|t}] = b^g_{t|t-1}(1-\phi_1-\phi_2) \\
+ (\pi^g_{t|t} - \pi^{e,i}_{t|t-1})\phi_1 \\
+ (\pi^g_{t|t} - (\pi^i_{t|t} - b^i_{t|t-1}))\phi_2
\end{aligned}
$$

and

$$
\begin{aligned}
E[b^i_{t+1|t}] = b^i_{t|t-1}(1-\omega_1-\omega_2) \\
+ (\pi^i_{t|t} - \pi^{e,i}_{t|t-1})\omega_1 \\
+ (\pi^i_{t|t} - (\pi^g_t - b^g_{t|t-1}))\omega_2
\end{aligned}
$$

True "persistence" of inflation experience (two types of households)

$$
\begin{aligned}
\mu_L - \mu &= (1-\alpha)(\mu_L - \mu_H) \\
\mu_H - \mu &= \alpha(\mu_H - \mu_L)
\end{aligned}
$$

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Bayesian Learning Model

Conjugate multivariate normal

Given prior beliefs $\vec{x}$ and a sample of signals $\vec{y}$ with marginal distribution $p(\vec{x})$ and conditional distribution $p(\vec{y}|\vec{x})$ of the form

$$\begin{aligned} p(\vec{x}) &\sim \mathcal{N}(\mu, \Lambda^{-1}) \\ p(\vec{y}|\vec{x}) &\sim \mathcal{N}(A\vec{x} + \vec{b}, L^{-1}) \end{aligned} \tag{1}$$

the conditional distribution of $\vec{x}$ after observing the sample of signals $\vec{y}$ (posterior distribution) is given by

$$p(\vec{x}|\vec{y}) \sim \mathcal{N}(\Sigma\{A^T L(\vec{y} - \vec{b}) + \Lambda\mu\}, \Sigma) \tag{2}$$

where

$$\Sigma = (\Lambda + A^T L A)^{-1} \tag{3}$$

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Experiments

What is the effect of "inaccurate" initial bias priors?

- True targets
  $[\pi, \quad E(b^p), \quad E(b^L), \quad E(b^H)] = [20, \quad -10, \quad 5, \quad -5]$
- Data
  $[\pi^g, \quad E(\pi^L), \quad E(\pi^H)] = [10, \quad 25, \quad 15]$
- Inflation Prior
  $[\pi_0] = [20]$

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Argentina: overshooting of inflation expectations

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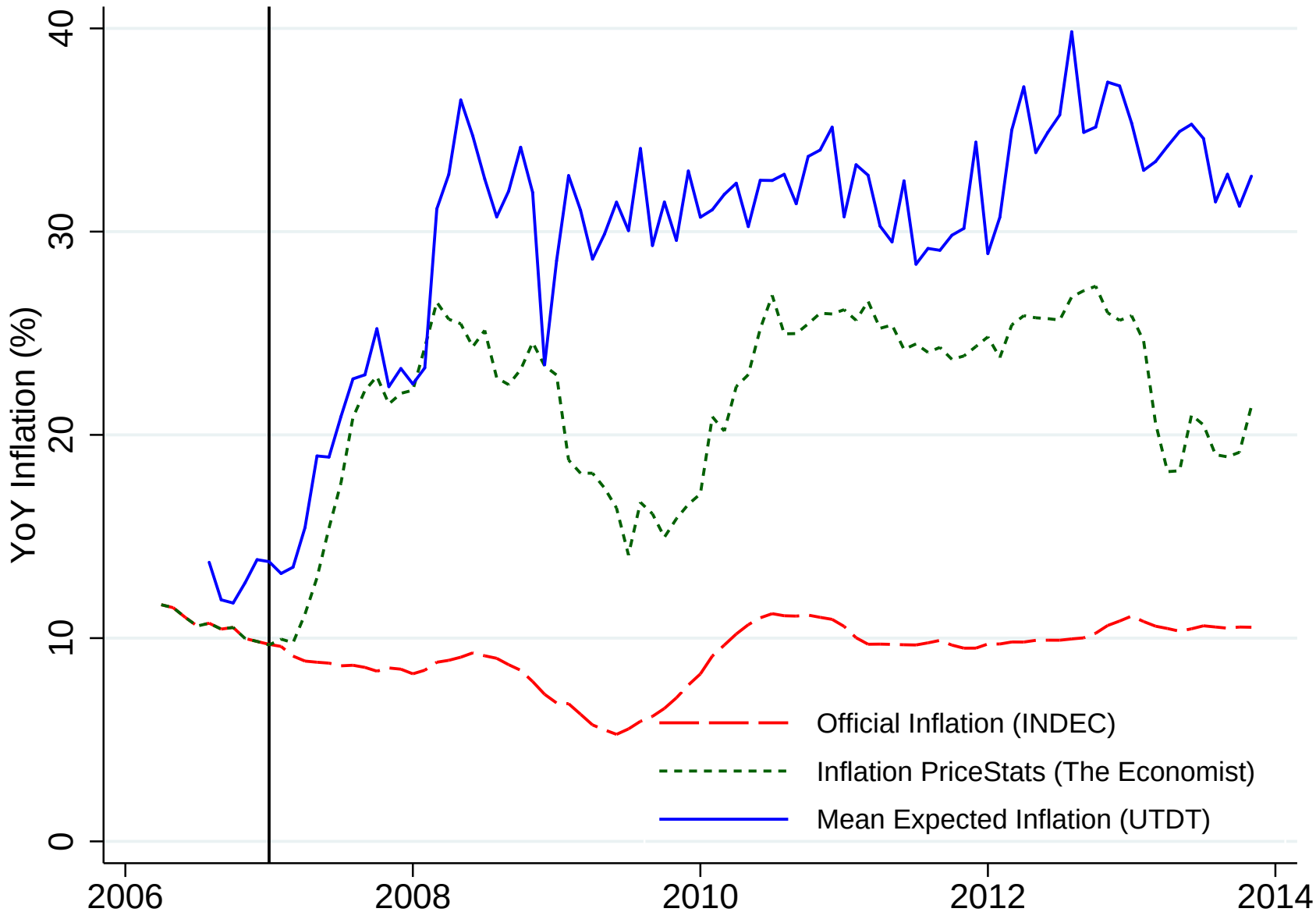

Argentina: expectations and experience

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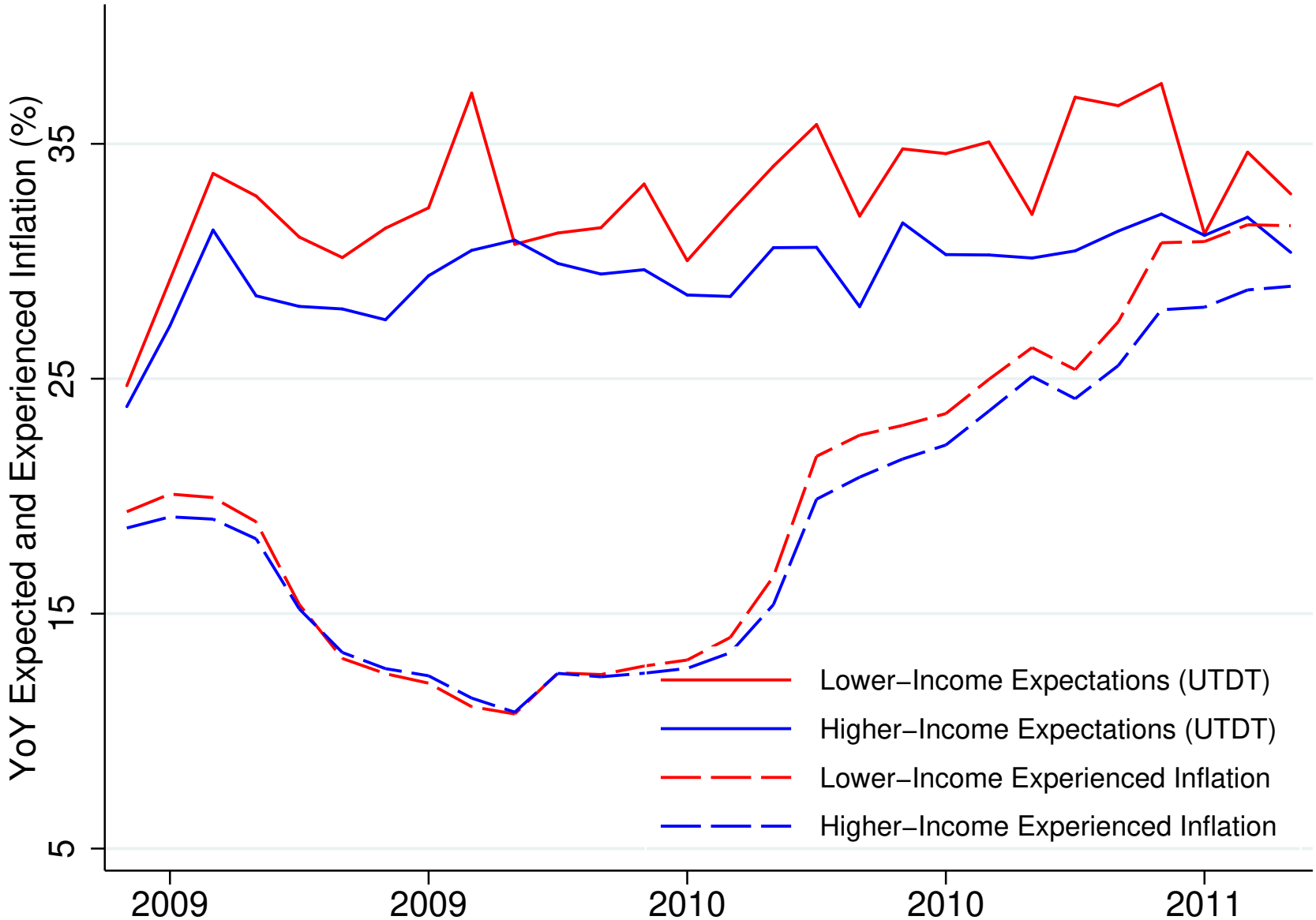
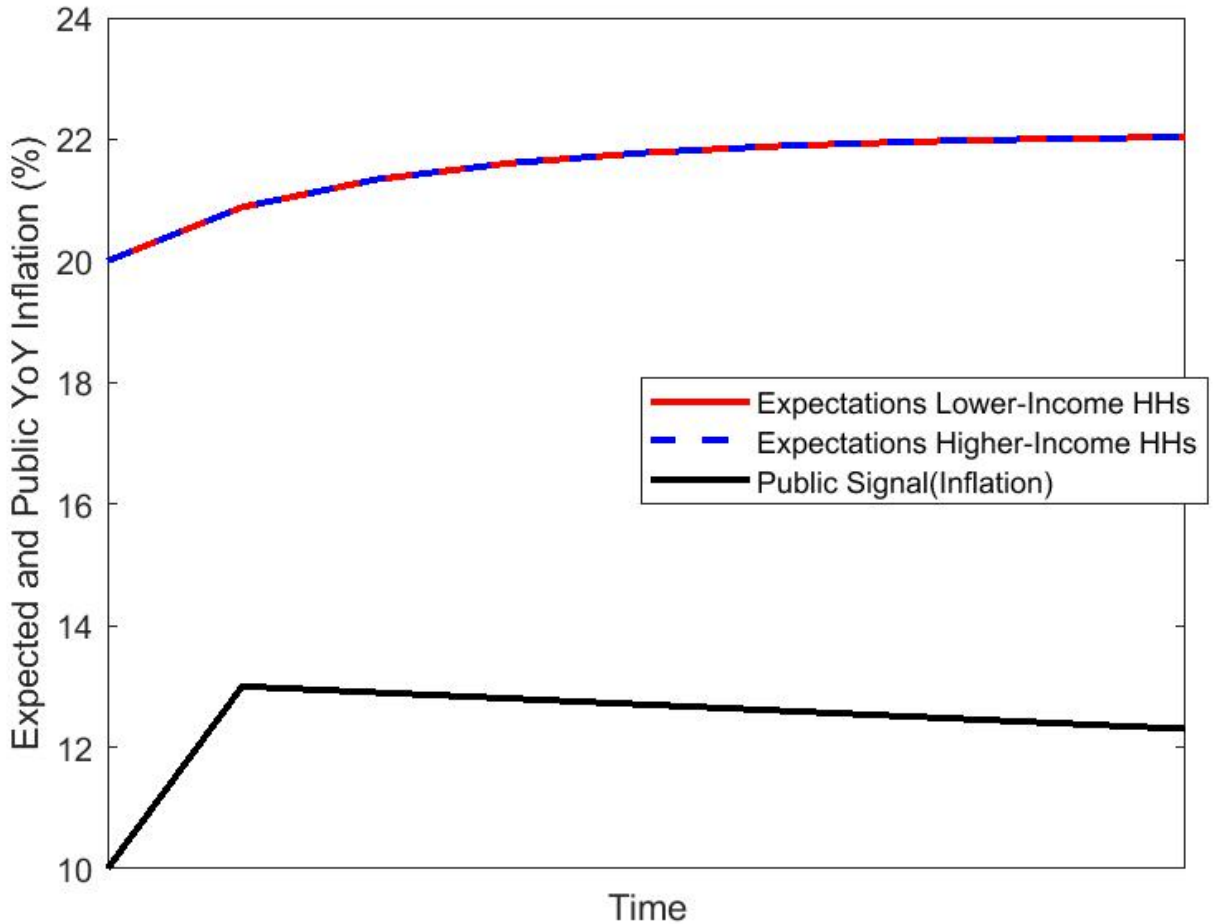


Official inflation and expectations in opposite directions



Example: Initial increase in public signal, either Back

- less bias in public signal $\rightarrow$ reduce perceived bias $(\pi^{p}_{t|t} - b^{p}_{t|t-1})$
- actual inflation is higher $\rightarrow$ experience "+" accurate $(\pi^{i}_{t|t} - b^{i}_{t|t-1})$

Other potential factors shaping expectations

- Other well known public signals
  - Robust to: utilities prices, gasoline prices, movements in the nominal exchange rate.

Back Back Conclusions

Bayesian Learning Model

- Decreased quality of public information vs. relative price dispersion
- Overshooting of expectations
- Use of both types of information

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Cross-sectional Evidence on the Level of Education

	(1) $\overline{\Pi}$	(2) $\overline{\Pi}$	(3) $\overline{\Pi}$	(4) $\Pi^{2007-2011}$	(5) $\Pi^{2007-2011}$	(6) $\Pi^{2007-2011}$
Low Educated	1.122***			8.224***		
	(0.0393)			(0.310)		
Kinder		0.741	0.733		5.474	5.431
		(1.249)	(1.244)		(9.865)	(9.817)
Primary		1.316***	1.162***		9.528***	8.196***
		(0.0416)	(0.0427)		(0.328)	(0.337)
Secondary		0.822***	0.717***		6.203***	5.285***
		(0.0447)	(0.0452)		(0.353)	(0.356)
Greater BA			0.653***			5.891***
			(0.0656)			(0.518)
Rest of ARG			0.781***			6.754***
			(0.0539)			(0.426)
Constant	19.33***	19.33***	18.75***	91.25***	91.25***	86.23***
	(0.0352)	(0.0351)	(0.0535)	(0.278)	(0.277)	(0.423)
Observations	25833	25833	25833	25833	25833	25833

Standard errors in parentheses

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

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