Inflation Expectations Formation in the Presence of Policy Shifts and Structural Breaks in Peru: An Experimental Analysis

Luís Ricardo Maertens Odria[(a)] Gabriel Rodríguez[(b)]
(a) Barcelona GSE, (b) Pontificia Universidad Católica del Perú

XXIX Meeting of the BCRP

October 2011

Contents

About the experiment

What is the purpose of the experiment?

- To gain insight as to how subjects forecast short-term inflation. Do they behave rationally? Do they behave adaptatively? Do they use heuristics?
- To determine how the uncertainty about these expectations evolves in time.
- To establish whether these two phenomena change with exogenous events.

About the experiment

Who participated in the experiment?

- Undergraduate and graduate students from PUCP.
- All participants had taken at least two courses in macroeconomics.
- All participants were required to complete two short online versions of the experiment.

About the experiment

How was the experiment implemented?

- We programed an online platform that allowed several participants to interact with a DSGE model at the same time.
- The model was calibrated so that it would fit the Peruvian economy.
- We ask our participants to predict future home inflation and give them adequate incentives to encourage careful forecasting.

Motivation

- The widespread use of expectations in macroeconomic models.
- The lack of sound theoretical and empirical evidence in favor rational expectations or learning algorithms (standard assumptions).
- The importance of accurately understanding how expectations are formed for policy purposes.
- The need to determine if expectations react to exogenous events and, if so, how?

Rational Expectations: "...expectations of firms (or, more generally, the subjective probability distribution of outcomes) tend to be distributed, for the same information set, about the prediction of the theory (or the "objective" probability distribution of outcomes)." (Muth, 1961: 316)
Problems:

- Heroic assumptions on the cognitive abilities of subjects and the availability of information.
- Mixed empirical support [Adam (2007), Branch (2007), Curtin (2005), Hey (1994), Mankiw et al. (2003), Pfajfar and Zakelj (2009), among others].
- Inability to replicate stylized facts of observational data.

Learning: Subjects are assumed to act as econometricians – adjusting their forecasting rules as information becomes available. [Evans and Honkapohja (2001)]
Bounded Rationality: Poses the biggest criticism to mainstream theories in expectations formation, urging economists to take into account people's cognitive limitations in modeling their behavior.
"To the best of my knowledge, all these [naïve, adaptative, and RE] equations have been conceived in the shelter of armchairs; none of them are based on direct empirical evidence about the processes that economic actors actually use to form their expectations about future events." (Simon, 1980: 308)

- Subjects tend to predict overly narrow confidence intervals. This is due to the use of the anchoring and adjustment heuristic. [Tversky and Kahneman (1974)]
- There is mixed evidence regarding whether subjects expect mean reversion even when it is bound to happen. [Kahneman and Tversky (1973), De Bondt (1993)] To our knowledge, this is the first experiment to test whether subjects expect inflation to revert to its mean.

The Model

Based on Galí and Monacelli (2005)

$$x_t = x_{t-1} - \frac{1}{\sigma_\alpha}\left(r_t - E_t^{AM}\left[\pi_{H,t+1}\right] - \overline{rr}\right) + \varepsilon_t^x \tag{1}$$

$$\pi_{H,t} = \beta E_t^{AM}\left[\pi_{H,t+1}\right] + k_\alpha x_t + \varepsilon_t^{\pi_H} \tag{2}$$

$$e_t = e_{t-1} + \lambda\left(r_{t-1} - r^*\right) + \varepsilon_t^e \tag{3}$$

$$\pi_t = (1-\alpha)\,\pi_{H,t} + \alpha\left(\Delta e_t + \pi^*\right) \tag{4}$$

$$r_t = \varphi_r r_{t-1} + (1-\varphi_r)\left[\varphi_\pi \pi_{t-1} + \varphi_x x_{t-1}\right] \tag{5}$$

We specify aggregate home inflation expectations to be the arithmetic mean of individual forecasts $E_t^{AM}\left[\pi_{H,t+1}\right] = \frac{\sum_{i=1}^{N} E_{i,t}[\pi_{H,t+1}|\Psi_{t-1}]}{N}$.

Table: Calibration of the Parameters of the Model

Parameter	Value	Parameter	Value
σ_α	3.85	λ	0.2
$\overline{rr}$	0.023	r^*	0.0283
β	0.9975	φ_r	0.7
k_α	0.084	φ_π	5
α	0.4	φ_x	1.67
π^*	0.0043		

Source: Authors' calibration, Castillo et al. (2009), and Vega et al. (2009).

Experimental Design

Implementation and Experimental Treatments

- We conduct 4 experiments in 9 group sessions. In each of these, 6 to 10 students participate.
- In the beginning, participants are able to see 15 past observations of all the variables in the model. Then, they are asked for their one-year-ahead home inflation forecast and its associated 95% confidence interval. (Caveat: We assume that the quarterized-one-year-ahead- and the one-quarter-ahead- home inflations are equivalent.)
- They are given appropriate incentives though the following payoff function:

$$p_{i,t} = \frac{10}{1 + |f_{i,t}|} + \frac{15 \cdot dum_t}{1 + CI_{i,t}} \tag{6}$$

$$\text{with } dum_t = \begin{matrix} 1 \text{ if } \pi^a_{H,t} \in [E_{i,t-1}[Ubound_{i,t+3}] \ , \ E_{i,t-1}[Lbound_{i,t+3}]] \\ 0 \text{ if } \pi^a_{H,t} \notin [E_{i,t-1}[Ubound_{i,t+3}] \ , \ E_{i,t-1}[Lbound_{i,t+3}]] \end{matrix} .$$

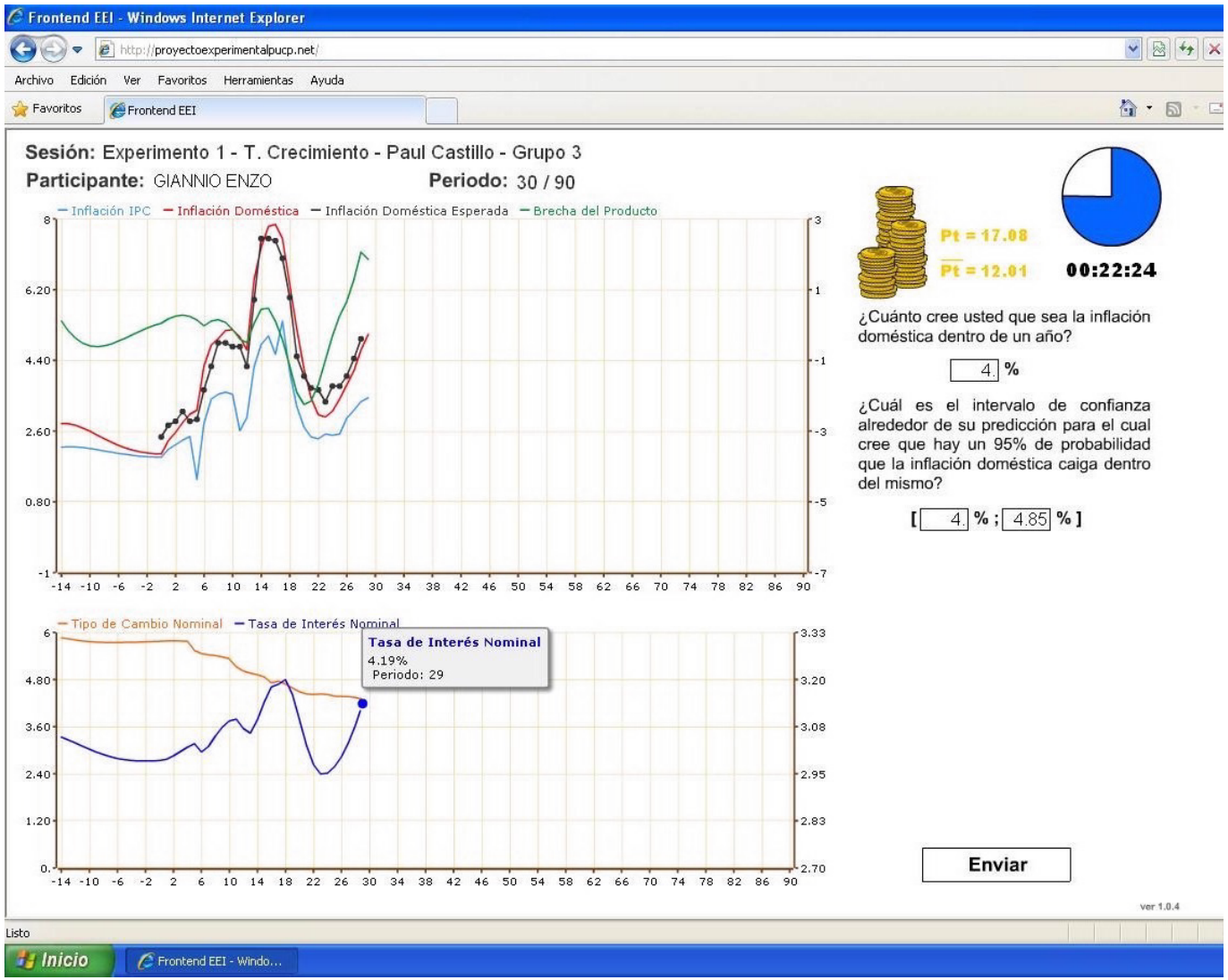
- This process is repeated for 44 periods while the model is sporadically exposed to home inflation, output gap, and exchange rate shocks.
- At period 46 one of the following unexpected events or treatments happens:

IT Adoption: Change in the parameters of Taylor's rule and a formal announcement by the Central Bank.
IT Announcement: Formal announcement by the Central Bank without increased reaction towards inflation.
IT with No Communication: Change in the parameters of Taylor's rule without a formal announcement by the Central Bank.
Recession: Large and negative output gap shock.

- Subjects are asked to keep forecasting for the last half of the experiment, while the model is exposed to the same shocks as in the pre-treatment period.
- At three periods during each session (one pre- and two post-treatment) we ask our participants: "What do you think is the percent chance that the home inflation will be less than Z?" for five different values of Z.

Experimental Design

Online Platform



Experimental Design

Unwanted range effects

Our design takes each individual as its own control; accordingly, we take appropriate measures to counter possible unwanted range effects [Greenwald (1976) and Poulton (1973)].

- *Carry-over* effects could arise in our experiments if the shocks that we introduce in our model persist at the time our experimental subjects are exposed to the treatment. In order to avoid this, we stop shocking the model seven periods prior to the introduction of each experimental treatment.
- *Practice* could also arise as an unwanted range effect if our participants are not familiar with the experimental setting and the task they are asked to undertake. We require our experimental subjects to practice interacting with our model prior to their scheduled group session.

Unbiasedness Test:

$$\pi^{a}_{H,t} = c + \beta E_{i,t-1}\left[\pi_{H,t+3} | \Psi_{t-2}\right] \tag{7}$$

Efficiency Test:

$$f_{i,t} = \beta_1 Y_{t-2} + \beta_2 Y_{t-3}$$

with $Y_t = \left[x_t, r_t, e_t, \pi_t, \pi_{H,t}\right]$.
When expectations are both unbiased and efficient, they are deemed rational.

Table: Rationality Test

	IT Adoption			IT Announcement			IT with No Communication			Recession		
Sample	U	E	R	U	E	R	U	E	R	U	E	R
Full	71	13	8	61	6	0	65	24	18	63	31	13
Pre	83	29	21	67	22	11	76	29	24	75	75	63
Post	100	50	50	83	44	33	76	29	29	81	44	31
New+	17	29	0	17	22	6	18	6	6	19	13	13
New-	0	8	0	0	0	0	18	6	0	13	44	0

Note: We report the percentage of participants in each experiment that passed the unbiasedness test (U), efficiency test (E), and both (R).

Results

Model Selection

We determine whether our participants' expectations formations processes can best be described as naïve (eq.8), adaptative (eq.9), trend extrapolative (eq.10), as following the anchoring and adjustment heuristic (eq.11) or as incorporating information from all the available variables (eq.12).

$$E_{i,t}\left[\pi_{H,t+4}|\Psi_{t-1}\right] = c + \beta\pi^{a}_{H,t-1} \tag{8}$$

$$E_{i,t}\left[\pi_{H,t+4}|\Psi_{t-1}\right] = c + \beta_1\pi^{a}_{H,t-1} + \beta_2 E_{i,t-1}\left[\pi_{H,t+3}|\Psi_{t-2}\right] \tag{9}$$

$$E_{i,t}\left[\pi_{H,t+4}|\Psi_{t-1}\right] = c + \beta_1\pi^{a}_{H,t-1} + \beta_2(\pi^{a}_{H,t-1} - \pi^{a}_{H,t-2}) \tag{10}$$

$$E_{i,t}\left[\pi_{H,t+4}|\Psi_{t-1}\right] = c + \beta_1(A_{t-1} + \pi^{a}_{H,t-1}) + \beta_2(\pi^{a}_{H,t-1} - \pi^{a}_{H,t-2}) \tag{11}$$

$$E_{i,t}\left[\pi_{H,t+4}|\Psi_{t-1}\right] = c + \beta_1 Y_{t-1} + \ldots + \beta_N Y_{t-N} \tag{12}$$

Table: Model Selection

	IT Adoption		IT Announcement		IT with No Communication		Recession		All (%)	
Naïve	0	[0]	0	[0]	0	[0]	0	[0]	0	[0]
Adaptative	2	[2]	2	[1]	1	[0]	2	[2]	9	[7]
Trend Extr.	8	[8]	4	[4]	4	[3]	7	[6]	31	[28]
A&A	6	[6]	3	[3]	9	[9]	6	[3]	32	[28]
Full Inf.	8	[5]	9	[7]	3	[1]	1	[1]	28	[19]

Note: We report the number of participants in each experiment whose expectations formation process can best be described, according to the Schwarz criterion, by the respective model. In brackets, we indicate how many of them pass the Chow Test for parameters stability.

Results

Mean-Reversion

The HTCI proposes that, when subjects expect home inflation to increase, they will predict left skewed confidence intervals $(S < 0)$ and vise versa when they expect said variable to decrease. We test this hypothesis by:

- Creating a measure of skewness (S) as follows:

$$\begin{aligned} S_{i,t} &= \left(E_{i,t}\left[Ubound_{i,t+4}\right] - E_{i,t}\left[\pi_{H,t+4}\right]\right) \\ &\quad - \left(E_{i,t}\left[\pi_{H,t+4}\right] - E_{i,t}\left[Lbound_{i,t+4}\right]\right) \end{aligned}$$

- Estimating the following equation by OLS and testing whether β is significantly smaller that 0.

$$S_{i,t} = c + \beta\left(E_{i,t}\left[\pi_{H,t+4}\right] - \pi^{a}_{H,t-1}\right) \tag{13}$$

Table: Asymmetric Confidence Intervals Hedging

		IT Adoption	IT Announcement	IT with No Communication	Recession
Incr. π	pre-	29	22	41	25
	post-	42	33	29	44
Decr. π	pre-	21	33	35	31
	post-	33	28	18	25
Incr. π_H	pre-	33	22	29	25
	post-	38	28	29	31
Decr. π_H	pre-	21	11	41	38
	post-	25	33	12	25

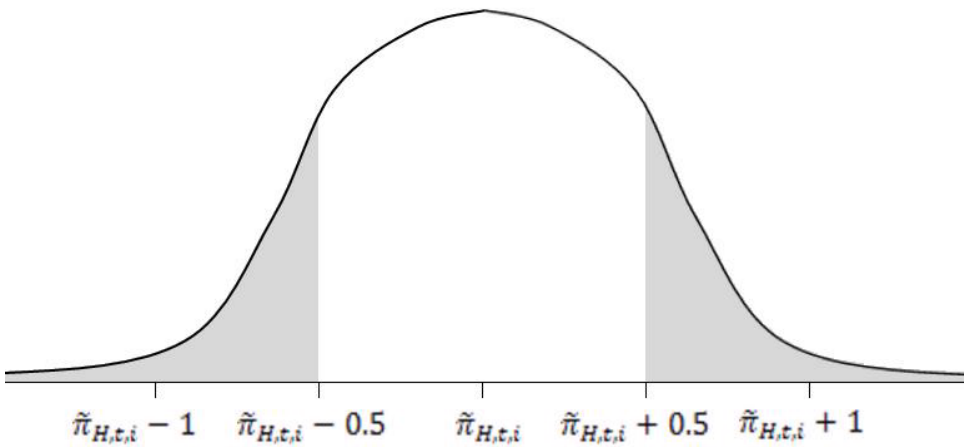
Note: We report the percentage of participants that passed the HTCI test.

Results

Uncertainty

We analyze whether the treatments that were implemented altered the way our participants perceived future home inflation uncertainty. To this purpose:

- We make use of our participants' answers to the questions "What do you think is the percent chance that the home inflation will be less than Z?" Since we ask this question for five different values of Z, we measure each participant's uncertainty, at time t, as the percent chance that the one-year-ahead home inflation will be less than $\tilde{\pi}_{H,t,i} - 0.5$ or greater than $\tilde{\pi}_{H,t,i} + 0.5$ - we call this measure $\Omega_{t,i}$.



- We designed all our experiments so that we could calculate $\Omega_{t,i}$ in the 30^{th}, 48^{th}, and 75^{th} periods. We do this because we are interested in measuring the average short run treatment effect (Δ^{sr}) and the average long run treatment effect (Δ^{lr}) in each experiment:

$$\Delta^{sr} = \sum_{i=1}^{N} (\Omega_{48,i} - \Omega_{30,i})$$

$$\Delta^{lr} = \sum_{i=1}^{N} (\Omega_{75,i} - \Omega_{30,i})$$

- Note that $\Omega_{30,i}$ and $\Omega_{75,i}$ are perfectly comparable since shocks in the pre- and post-treatment samples were the same and our design controls for unwanted range effects.

Table: Dispersion Analysis

	IT Adoption	IT Announcement	IT with No Communication	Recession
Pre-treatment mean dispersion	60.63	62.81	52.33	58.67
	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Δ^{sr}	-13.56	-1.63	-3.18	3
	[0.0738]	[0.8188]	[0.7453]	[0.6837]
Δ^{lr}	-8.42	4.25	-0.67	7.80
	[0.2527]	[0.5734]	[0.9399]	[0.2370]

Notes: (1) We report regression coefficients. (2) P-values are shown in brackets.

Concluding Remarks

Expectations and Policy Shifts (IT)

- In the context of inflation forecasting, our experiments provide evidence against the rationality assumption, as only 9.3% of all our participants could be described as having both unbiased and efficient expectations throughout the whole experiment.

Concluding Remarks

Expectations and Policy Shifts (IT)

- In the context of inflation forecasting, our experiments provide evidence against the rationality assumption, as only 9.3% of all our participants could be described as having both unbiased and efficient expectations throughout the whole experiment.
- Past trends play a central role in the expectations formation process. 63% of our participants' expectations could be best described by trend extrapolative and anchoring and adjustment models.

Concluding Remarks

Expectations and Policy Shifts (IT)

- Our findings highlight the importance of the availability of new information on our participants' expectations formation processes. In the IT adoption and IT announcement experiments, rational forecasting among our experimental subjects increased by 29% and 22%, respectively.

Concluding Remarks

Expectations and Policy Shifts (IT)

- Our findings highlight the importance of the availability of new information on our participants' expectations formation processes. In the IT adoption and IT announcement experiments, rational forecasting among our experimental subjects increased by 29% and 22%, respectively.
- Additionally, we found that, conditional on CPI or home inflation variations, there was a significant increase in the percentage of subjects that expected home inflation to revert to its mean – or target.

Concluding Remarks

Expectations and Policy Shifts (IT)

- Our findings highlight the importance of the availability of new information on our participants' expectations formation processes. In the IT adoption and IT announcement experiments, rational forecasting among our experimental subjects increased by 29% and 22%, respectively.
- Additionally, we found that, conditional on CPI or home inflation variations, there was a significant increase in the percentage of subjects that expected home inflation to revert to its mean – or target.

- The adoption of IT proved to have a significant short-run effect over average home inflation uncertainty, reducing it by 13.6%.

Concluding Remarks

Expectations and Structural Breaks (Recession)

- There was a 32% decrease in the amount of participants that forecasted in a rational fashion.

Concluding Remarks

Expectations and Structural Breaks (Recession)

- There was a 32% decrease in the amount of participants that forecasted in a rational fashion.
- We found evidence in suggesting that subjects are non-linearly inattentive. Most of our participants ignored the output gap, for forecasting purposes, throughout the experiment; yet, the recession induced a 19% increase in the amount of subjects that complied with the HTCI.

Concluding Remarks

Expectations and Structural Breaks (Recession)

- There was a 32% decrease in the amount of participants that forecasted in a rational fashion.
- We found evidence in suggesting that subjects are non-linearly inattentive. Most of our participants ignored the output gap, for forecasting purposes, throughout the experiment; yet, the recession induced a 19% increase in the amount of subjects that complied with the HTCI.
- The recession increased perceived uncertainty about future home inflation in the short- and long-run, yet these results were not statistically different from zero.