#### Inflation Expectations & Cognitive Economics

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# Outline

#### Introduction

- Modeling Inflation Expectation Formation
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- Experimental Approach
- Policy Implications

# Introduction

- Inflation expectations are the rate at which people expect prices to rise in the future. Actual inflation depends, in part, on the expected inflation.
- The role of expectations in the inflation process has been hotly debated over the years. Although economists agree that inflation expectations matter, there is not yet consensus about which inflation expectations matter. Forward-looking new Keynesian models or backward-looking models? If we understand people's inflation expectations better, we can make more informed decisions.
- Three key variables for which inflation expectations are relevant: Real Interest Rate, Wage Setting and Price Setting
- Bernanke(2022): The role of inflation expectations in monetary policy:
- 1) Inflation expectations are important determinant of realized inflation
- 2) Central bank behavior (communications strategies) can influence inflation expectations and through them macroeconomic outcomes.

6/14/2023

- If inflation expectations are well anchored, they should be relatively insensitive to news. Therefore, they can help stabilize inflation faster in case of supply and demand shocks.
- Inflation expectations in developing countries and in developed countries
- Inflation Expectations' Anchoring: an inflation targeting regime, high central bank transparency, strong trade integration, and a low level of public debt.
- Inflation expectations are very unstable in Iran's economy because the Central Bank is unable to adhere to an inflation target in practice. Thus, inflation expectations are not well-anchored and any shock results in inflation and causes private agents to raise inflation expectations. This in turn will increase inflation. As a result, poor anchored inflation expectations make price stability much more difficult to achieve in the long run and decrease the Central Bank's ability to stabilize output and employment in the short run.
- Budget deficit and monetary base
- It matters for the Central Bank to know how private agents form their expectations. Moreover, optimal monetary policy depends considerably on the assumed nature of expectations formation process.

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#### Modeling Inflation Expectation Formation

#### Near Rational Expectations

- Adaptive Exp.
- **Static Exp.**

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- **Extrapolative Exp.** 
  - Normal Exp.
- Rational Expectations
  - The rise of Rational Expectations The general characteristics of RE General critique of RE
- Learning Approach

# Learning Process

- Learning in macroeconomics refers to models of expectation formation in which agents revise their forecasting rules over time as new data becomes available (Evans & Honkapohja, 2001).
- Role of learning in macroeconomics :
- □ 1) Stability under learning
- 2) Structural change in economy.
- 3) A selection criterion when a model has more than one equilibrium solution.



# Approaches to learning

Eductive learning
Adaptive learning
Rational learning

**Eductive Learning:** in this approach, we examine whether expectations converge to the rational expectations equilibrium through a process of reasoning. Consider the demand and supply in a market are given by

$$q_t = c + dp_t^e + v_t$$
$$q_t = a - bp_t + w_t$$

The reduced form for the prices is given by

$$p_t = A - Bp_t^e + u_t$$

The model under RE:  $p_t^e = E(p_t | \mathbf{I}_{t-1}) = \overline{E_{t-1}p_t}$ 

We can compute RE as  $p_t = A - BE_{t-1}p_t + u_t$ 

Taking conditional expectations  $E_{t-1}p_t$  of both sides yields

$$E_{t-1}p_t = \frac{A}{1+B}$$

The model under Eductive learning: Expectations will converge to RE The rational expectations, in this case, is said to be iteratively E-stable (|B| < 1).

Now we consider the model under eductive learning. Suppose agents form their expectations initially in an arbitrary manner, for example, static expectations

$$E_{t-1}^0 p_t = p_{t-1}$$

- The question is whether they can modify their behavior so that rational expectation equilibrium, given by  $\frac{A}{1+B}$ , would be attainable.  $p_t = A - Bp_{t-1} + u_t$
- It is assumed that after some passage of time agents realize (reason or deduce) that prices are evolving and form new expectation

 $E_{t-1}^1 p_t = A - B p_{t-1}$ 

$$p_t = A - B(A - Bp_{t-1}) + u_t = A - BA + B^2 p_{t-1} + u_t$$

$$E_{t-1}^2 p_t = A - BA + B^2 p_{t-1}$$

 $E_{t-1}^{n}p_{t} = A - BA + B^{2}A - B^{3}A + \dots + B^{n}A + B^{n}p_{t-1} = A(1 - B + B^{2} - B^{3} + \dots + B^{n}) + B^{n}p_{t-1}$ 

for  $|\mathbf{B}| < 1$  and large n

$$E_{t-1}^n p_t = \frac{A}{1+B}$$

6/14/2023

- **Adaptive Learning:** Assume that the reduced form for prices is as  $p_t = \overline{A - Bp_t^e} + Cz_{t-1} + \overline{u_t}$
- RE:  $E_{t-1}^{n} p_{t} = \frac{A + Cz_{t-1}}{1 + B}$ Suppose agents perceive the reduced form as a linear regression The recursive least-squares estimates can be shown to be

$$\beta_{t} = \beta_{t-1} + \gamma_{t} R_{t}^{-1} x_{t-1} (y_{t-1} - \beta_{t-1}^{'} x_{t-1})$$

$$R_t = R_{t-1} + \gamma_t (x_{t-1} x_{t-1} - R_{t-1})$$

- The conditions for convergence of recursive least-squares expectations (B < 1)can be weaker than those under iterative expectations (|B| < 1).
- Stability under adaptive learning:
- Perceived law of motion (PLM):  $p_t = \alpha + \beta z_{t-1} + u_t$

Actual law of motion (ALM):  $p_t = (A - B\alpha) + (C - B\beta)z_{t-1} + u_t$ A model is stable or learnable if the new data generated by one more observation under learning is on average closer to the REE than the current belief derived from 10

#### Forming Expectations using Adaptive Learning Model

$$\pi_{t|t+1} = b_{1,t} + b_{2,t}\pi_{t-1} + b_{2,t}y_{t-1} + \mathcal{E}$$

$$B_{t} = B_{t-1} + t^{-1}R_{t}^{-1}X_{t}(\pi_{t} - X_{t}^{'}B_{t-1})$$

$$R_{t} = R_{t-1} + t^{-1}(X_{t}X_{t}^{'} - R_{t-1})$$

$$B_{t} = (b_{1,t}, b_{2,t}, b_{3,t})^{'} \qquad X_{t} = (1, \pi_{t-1}, y_{t-1})$$

The equations above correspond to the following State Space Model (Harvey ,1993)

$$\pi_{t|t+1} = b_{1,t} + b_{2,t}\pi_{t-1} + b_{2,t}y_{t-1} + \varepsilon_{t}$$
$$b_{i,t} = b_{i,t-1} + v_{i,t}$$

Rational Learning: the widely used method to model rational learning has been based on Bayes' theorem. It is a method of updating belief, implying that beliefs change by learning. Data or new facts only influence the posterior belief, P (A | B), through the likelihood function P (B | A)

 $P(A|B) = \frac{P(B|A)P(A)}{P(B)}$ 

where P(A) is prior belief. Many researchers used Bayes' rule to model learning in the economic literature including learning about a new regime (Ellison and Valla, 2000).

- An innovation based on computational intelligence has been the use of Neural Networks. The convergence of learning to the rational expectations equilibrium using neural networks is of our interest. In fact, we are interested in knowing whether the private agents are able to learn to form rational expectations with help of neural networks.
- Assume the reduced form for prices is as
- The rational expectation function will be learnable using the Back-Propagation neural network if  $\alpha < 1$





 $p_t = \alpha p_t^e + h(x_t) + \varepsilon_t$ 



#### Cognitive Economics: A New Approach to Human Behavior in Economics

• <u>Cognitive Science</u>: the scientific study of the human mind. The field is highly interdisciplinary, combining ideas and methods from psychology, computer science, linguistics, philosophy, and neuroscience.

# Cognitive Economics: Economics of what is in people's minds.

- Cognitive economics includes survey data on expectations, self-reported happiness, direct measures of intelligence and decision-making skill.
- Survyey Data: heterogeneity across individuals
- Which types of cognitive abilities(quantitative, verbal and visuospatial) might matter to explain the heterogeneity in inflaion expections across individuals? Policymakers will design different strategies for diffrent subpopulations.



# **Expectations Formation Process: An Experimental Approach**

- Cognitive economics includes data on expectations.
- The experiment will consist of N independent groups of people.
- People know the model and provide their inflation forecast for period t+1. The expected inflation is calculated as the point forecast of inflation.
- ALM:  $\pi_{t+1} = \gamma_0 + \gamma_1 \pi_{t-1} + \gamma_2 \pi_{t-2} + \gamma_3 y_{t-1} + \gamma_4 y_{t-2} + \gamma_5 \dot{i}_{t-1} + \varepsilon_t$ 
  - PLM:  $\pi_{t+1|t}^{k} = \beta_0 + \beta_1 \pi_{t-1} + \beta_2 \pi_{t-2} + \beta_3 y_{t-1} + \beta_4 y_{t-2} + \beta_5 i_{t-1} + \varepsilon_t$
- In order to test that a person has RE: the estimated coefficients in both regressions should not be statistically different  $H_0: \mu_i = \gamma_i - \beta_i = 0$

$$\pi_{t+1} - \pi_{t+1|t}^{k} = \mu_0 + \mu_1 \pi_{t-1} + \mu_2 \pi_{t-2} + \mu_3 y_{t-1} + \mu_4 y_{t-2} + \mu_5 i_{t-1} + \varepsilon_t$$

#### HP filter as a proxy for rational expectations series

Assume that  $\pi_t^f$  denotes a proxy for a rational forecast of  $\pi_t$ , where  $\pi_t$  is inflation rate series and  $\pi_t^f$  the corresponding HP filtered series. To test for unbiasedness, we first run the following regression

 $\overline{\pi_t} = \overline{a_0} + \overline{a_1} \pi_t^f + \varepsilon_t$ 

- Necessary condition: joint hypothesis  $a_0 = 0$  and  $a_1 = 1$ Sufficient condition:  $\pi = \pi^e - F = 0$  The hypothesis to
- Sufficient condition:  $\pi_t \pi_t^e = E_t = \mu_t + \varepsilon_t$  The hypothesis to test is  $\mu = 0$ .
- To test for efficiency, a test of joint hypothesis  $b_1 = b_2 = 0$  is needed based on the following regression

$$\pi_{t} - \pi_{t}^{e} = b_{1}(\pi_{t-1} - \pi_{t-1}^{e}) + b_{2}(\pi_{t-2} - \pi_{t-2}^{e}) + \varepsilon_{t}$$

### **Model Selection**

- Out of sample forecasting performance is used to compare the different kinds of expectation formation. An individual is regarded as being best described by the expectation formation model which produced the lowest RMSE.
- Economic research using more and more direct data on what is in people's minds is flourishing.
- New surveys can be desighted and new data of many kinds can be collected to answer pressing questions.
- Cognitive Economics models behavior more realistically (for example, 30% of people described by Rational Model, 40% of people Adaptive Learning Model, 30% of people Static Model).

# **Policy Implications**

- Since the learning approach is better suited for modeling inflation expectations than other alternative methods, the Central Bank should be more aggressive towards inflation. The optimal monetary policy under a learning process should be more aggressive and narrowed to inflation stability.
- Furthermore, as any decrease in inflation is highly desirable and is one of the main macroeconomic goals, solidly anchored inflation expectations are suggested. To do so, we need to keep monetary policy tight for a considerable period. However, it should be noted that conducting such policy will also decrease output and employment.

The Central Bank should be independent so that it is able to adhere to an inflation target in practice. In this case, the monetary policy will be more credible so that it makes the private agents' expectations more responsive to signals from the Central Bank and the agents know what to expect following a set of published inflation targets.

# Thank you !