THE INTERNATIONAL JOURNAL OF HUMANITIES & SOCIAL STUDIES

Application of Experimental Methods in Expectation Formation and Learning in Macroeconomics

Abhishek Das
Research Scholar, Department of Economics, Jadavpur University, Kolkata, India
Gautam Gupta
Professor, Department of Economics, Jadavpur University, Kolkata, India

Abstract:
Application of experimental methods in macroeconomics is a comparatively new approach that investigates various aspects of macroeconomic theories. This article traces the evolution of the application of experimental methods in expectation formation in macroeconomics.
JEL Classification: C91, C92, D84

Keywords: *Rational expectation, bounded rationality, heterogeneous expectation, learning*

1. Introduction

Macroeconomics has never been a subject amenable to laboratory experiments.

"Laboratory experiments using macroeconomics are rarer than those using microeconomics...I suspect that the main reason for fewer experiments in macro than in micro is that the choices confronting artificial agents within even one of the simpler recursive competitive equilibria used in macroeconomics are very complicated relative to the settings with which experimentalists usually confront subjects."

Sargent[1] (2008)

In spite of Sargent's (2008) statement a wide variety of macroeconomic models and theories have been examined using controlled laboratory experiments with paid human subjects. Experiments not only help us to evaluate important assumptions of modern macroeconomic models but also examine the implications of different types of public policy.

Central bankers are facing difficulties in implementing monetary policy taking into account the complex nature of economic behaviour and uncertainty. How economic agents form their expectations about the future of the economy is the fundamental question before the Central Banks. Several theoretical models have been developed to explain the formation of expectations but proper empirical validations of these theories have not been done rigorously. Many economists emphasized the importance for policy-makers to understand how expectations affect the conduct of monetary policy, and vice versa. Empirical evidence regarding the formation of inflation expectations is not readily available for all the model specification, so researchers have applied experimental economics to help fill this important gap.

It should be mentioned that there are surveys taken to estimate how economic agents form expectations about future inflation rates, but it is a moot question if people would react in real-life situations as they have reacted in the survey. This often leaves conducting experiments with human subjects and monetary incentives the only option for estimating how expectations are formed in the economy. In the following sections we review the evolution of the application of experimental methods in this field.

2. Expectation Formation and Learning

In modern macroeconomics expectation about future endogenous variables play an important role in determination of current values of those endogenous variables. Since the influential works of Muth (1961) and Lucas (1972), the Rational Expectations Hypothesis (REH) has turned into the foremost model on expectation formation in economics. Not only that, in spite of several criticisms rational expectations representative agent models have become the mainstream tool for analyzing various monetary policies. In the REH framework, agents are homogeneous and they use all the available information for forecasting rationally so that there are no systematic forecasting errors.

First generation experimental tests of REH involved subjects' forecasts of exogenously given stochastic processes for prices. The first example in this area is Fisher (1962). Schmalensee (1976) presented a total of twenty-three subjects with price observations from a

[1] Nobel Prize Lecture. Thomas Sargent was the recipient of Nobel Prize in economics in 2008

nineteenth-century British wheat market and asked subjects to predict the mean wheat price for the next 5 periods based on the historical data of wheat prices. They did not analyze the data to look for support of the Rational Expectation Hypothesis.

Garner (1982) used an experimental set up where actual price observations were generated by a reduced form supply and demand model with hypothetical data and parameters of a fictitious agricultural commodity and twelve subject's were asked to submit forecasts of the price of that commodity. After the price forecasts were entered, the actual price was announced and subjects submitted new forecasts. Garner concluded that his forecast data "revealed departures from Muthian rational expectations," but that subjects forecasts corresponded fairly well with price predictions generated by a least-squares learning model.

Smith et al (1988) ran an experiment on an asset market. They found that "a common dividend and common knowledge thereof is insufficient to induce initial common expectations". This is due to uncertainty about other agents' behaviour. As more experience is gathered by each subject they tend to converge with Rational Expectation equilibrium in the sense of Muth.

Kelley and Friedman (2002) considered learning in an Orange Juice Futures price forecasting experiment, where prices were driven by a linear stochastic process with two exogenous variables (weather and competing supply).

But in these papers there is no expectations feedback, since market realizations are not affected by individual forecasts i.e. these are not *learning to forecast experiment*[2]. Due to some strong assumptions[3] in REH, many researchers began to endorse the Bounded Rationality Hypothesis (BRH) as an alternative mathematical model of decision making. According to BRH, rationality of an individual is limited in respect to information, cognitive ability and time (see, Sargent (1993, 1999) and Evans and Honkapohja (2001)) for surveys of the theoretical literature).

There are two approaches of bounded rational expectations found in the experimental literature relevant to macroeconomics. The first one is 'step-level' reasoning (Duffy, 2008). This part is driven by Keynes's (1936) famous comparison of financial market investors' expectations to newspaper beauty contest game. In this game participants had to select the six prettiest faces from one hundred photographs. The winner of the contest was the person whose choices were closest to the average choices of all competitors[4].Here one important point is that individuals might form expectations not just of average opinion, but might also consider what average opinion expects average opinion will be. These observations concerning expectation formation were tested experimentally by Nagel (1995) in a game developed by Moulin (1986).

Here we will first discuss the basic beauty contest game by Nagel (1995) and then look at some variations of it. In the basic game, N participants are asked to guess a number from the closed interval [0,100]. The winner is the person whose guess is closest to p times the mean of the choices of all players. Where p is common knowledge to all. The winner gets a fixed amount which is independent of the stated number and p. In case of a tie the prize is split amongst those who have tied. Others player of the game will not get anything. According to game theory, for $0 \leq p < 1$, there exist only one Nash equilibrium rational expectation solution. This implies the existence of a reference level of reasoning by the agents. Whereas, in case of $p = 1$, any number in [0,100] is a rational expectations equilibrium and one cannot distinguish between different steps of reasoning by actual subjects in an experiment. Nagel choose p =1/2, 2/3 and 4/3 for session 1-3, session 4-7 and session 8-10 correspondingly and ran the game for 4 periods in each session. The main experimental result is that the equilibrium prediction of 0 is never chosen. Also, the mean prediction value converges towards zero over time.

This beauty contest game experiment has been replicated many times (see, Duffy and Nagel(1997), Ho et al. (1998), Bosch-Domenech et al. (2002), Weber (2003), Slonim (2005), Kocher and Sutter (2005), Grosskopf and Nagel (2008), Eileen et al (2009)). We see that multi-agent economies, where all agents know the model, do not produce a rational expectation solution. It further suggests that existence of convergence to equilibrium indicates that there is a systematic forecast error which is corrected over time. This implies that rational expectations might be best viewed as a long run phenomenon.

Now, in the second approach of bounded rational expectation formation, it is posited that agents do not have any knowledge about the underlying model and they update their forecasts as new observations become available. Learning to forecast experiments have been conducted within a simple macroeconomic setup (see Williams (1987); Marimon, Spear and Sunder (1993); Evans, Honkapohja, and Marimon (2001); Arifovic and Sargent (2003); Adam (2007)) and also within the asset pricing framework (see Hommes, Sonnemans, Tuinstra, and van de Velden (2005) and Anufriev and Hommes (2011)). These studies mainly focus on the aggregate expectations formation and tend to reject the rational expectations assumption in favour of adaptive manner of forming beliefs. Here we will discuss some of the papers.

---

[2]In learning to forecast experiment (LtFE) "subject's only task is to forecast the price of some commodity for a number, say 50-60, periods, with the realized market price in each period determined by (average) individual expectations. In LtFEs subjects' forecasting decisions are thus separated from market-trading decisions. The subjects in the experiments do not participate themselves directly in other market activities, such as trading or producing, but are forecasters (e.g. advisors to large producers or financial investors) whose earnings increase when forecasting errors decrease" (Hommes, 2011).

[3]Some of these strong assumptions are:

a. All agents are rational and this is common knowledge
b. Agents know with certainty the underlying model

[4]"each competitor has to pick, not those faces which he himself finds prettiest but those he thinks likeliest to catch the fancy of other competitors, all of whom are looking at the problem from the same point of view." Keynes (1936, p. 156)

Marimon and Sunder (1993, 1994, and 1995) were the first to investigate inflation forecasts through experiments in an overlapping generation model[5] (OLG) framework. The basic experimental design is as follows: three sets of subjects are there. First and second set of subjects are playing a role of young and old respectively and third group of subjects are kept as reserve subjects. Young subjects are given some unique commodity called chips, they can either consume in the present period or sell it to the old group for money which they can carry forward to the next period. And in case of old group they have to consume all of their endowment in the current period as there is no provision of bequest in the model. The market clearing price is determined by the demand and supply of the chip. After the first period young become old, old become reserve and reserve become young. And this process is continuous.

Marimon et al (1993) first studied the indeterminacy of equilibria. They did not find any non-stationary rational expectation path. They observed that rate of inflation tends to converge close to, or somewhat below, the low inflationary stationary state. They identified sunspot equilibria in the experimental framework. They found that "if agents expect sunspots to matter, they can matter" (Marimon et al, 1993). More specifically if economic agents believe that some random events matter in price determination, such beliefs can be self-fulfilling even when these events are extrinsic to the economy. Their data shows that even though the real source of uncertainty disappears from the economy, agents' behaviour may show enough inclination to sunspot fluctuations. They find that there is evidence in favour of adaptive expectations rather than rational expectations. Bernasconi & Kirchkamp (2000) considered subjects' optimal savings decision with the same theoretical model. They found the existence of adaptive expectations.

Hommes et al (2007) considered expectation formation by groups of six subjects in the Cobweb model for 50 periods. Subjects were asked to forecast price for the $(t+1)^{th}$ period on the basis of price information up to $(t-1)$ while being in period t. They were also asked to restrict their forecast between 0 and 10. Supply of a good was determined by these forecasts and a parameter. And this supply was positively related to inflation expectations. Demand was exogenously given. They incorporated a small shock in the demand function. In Hommes et al (2007) framework the equilibrium price was determined by the expectation of subjects' and that shock. In this experimental frame work each subject knows the common past history and her own expectations but are not informed about the process of expectation formation. Subjects' payoff was a decreasing function of prediction error. The treatment variable was variation in the parameter which maintained the nonlinearities in the supply function. According to rational expectations, all forecasts should be same at a given price level. They found that the mean price expectation was not significantly different from the RE value, though the variance was significantly greater than RE value in case of unstable and strongly unstable treatments. They found that the autocorrelations were not significantly different from zero with no predictable structure to these autocorrelation. This implies "subjects are not behaving in an irrational manner in the sense that there is no unexploited opportunity for improving price predictions" (Hommes 2007). Therefore Hommes et al supported rational expectations.

Adam (2007) used a two-equation, multivariate New Keynesian "sticky price" model (see, , Woodford (2003)). In his framework inflation and output gap was determined by a difference equation consisting of a one period and a two period ahead expectation. Like Hommes et al (2007) Adam asked subjects to predict inflation for the next two periods (t and ($t+1$)) on the basis of information about inflation and output gap up to period t-1. Here also, through the realised value generated, inflation and output gap was public information but not the underlying model. . Subject payoff was dependent on forecast accuracy. Adam finds that most of the subjects were forecasting by using the autoregressive inflation model which finding was different from Hommes et al (2007). He also found that subjects' forecast do not depends on lagged output, which implies their prediction was not following rational expectation process because in his frame work equilibrium inflation was dependent on lagged output gap. He called it "restricted perceptions" equilibrium. Adams further concluded that this miss-specification in agents' forecasts provided a further source of inflation.

Pfajfar and Zakelj (2013) used a three-equation forward looking multivariate New Keynesian model. Interest rate rule was the one extra equation added over Adams (2007) framework. In the standard forward looking New Keynesian model (Woodford 2003) expectation is attached to both inflation and output gap, but Pfajfar and Zakelj (2013) replaced the output gap expectation with current level output gap. They use two types of Taylor principle and various values of central banks' aggressiveness as treatment variables. Subjects are asked to forecast inflation only, on the basis of historical time series on inflation, the output gap and interest rates. They found that there is a significant and relatively large proportion of agents' behaviour consistent with the assumption of rationality. The remaining subjects are using various kinds of adaptive expectations, adaptive learning or trend extrapolation rules. They found that subjects' expectations are heterogeneous both across subjects and over time. Most of the subjects were switching between various rules of expectation formation and learning. In their experimental framework more than 1/3 of the forecasting decision was generated through adaptive learning models.

Assenza et al. (2013) conducted an experimental study similar to that of Pfajfar and Zakelj (2013), but with some important differences. They considered forecasts of both future inflation expectation and of the future output gap expectation in one treatment. In this treatment there were two groups of participants acting in the same economy but with different tasks: one group forecasts inflation while another forecast output gap. They found that there existed adaptive learning rule in all the treatments and subjects' used a consistent linear prediction rule. Like Pfajfar and Zakelj (2013) they also found switching behaviour of the subjects.

Das et al (2013) also conduct an experimental study similar to that of Pfajfar and Zakelj (2013) and Assenza et al. (2013), but with some modification over the existing literature. They used a New Keynesian model where same subjects are asked to forecast both the

[5]The concept of Overlapping Generations (OLG) model with money in the economy was first introduced by Samuelsotn (1958), and extended by Wallace (1980, 1981) and Sargent (1987). The standard OLG model assumes that the individuals in the economy live for two periods only – labelled young and old. The name behind the OLG model is coexistence of two generations (the young generation is born at the beginning of the current period and other, old generation who were born in the preceding period and die at the end of the current period) in the framework.

inflation and output gap for the next period on the basis of historical time series on inflation, the output gap and interest rates. Existence of rational expectation was found to be low in their framework but their model shows switching by the subjects.

Bao et al. (2013) used a similar set-up as Hommes et al (2007) in a Cobweb framework but their main focus was to compare the performance of the "learning-to-forecast" (LtFE) experimental design with "learning-to-optimize" (LtOE) design. Their experiment consisted of 4 treatments. In treatment 1 (LtFE treatment), subjects (firms) only made price forecasts. Each firm's production decision was calculated by the computer optimally, given the firm's price forecast. Each subject was paid according to the accuracy of her forecast alone. In treatment 2 (LtOE treatment), subjects (firms) only made quantity (or production) decisions. The market clearing price was determined by the production decisions submitted by all firms in the market. Each subject was paid according to the profit her firm made in each period. In treatment 3(LtFE+LtOE Individual treatment), each subject was asked to make both a price forecast and a quantity decision.The market clearing price was determined by the quantity decisions of all firms in the market. Subjects were paid according to an equally weighted linear combination of the payoff functions used in the LtFE and LtOE treatments. In treatment 4(LtFE+LtOE team treatment), there was a forecaster and a production manager in each team. The forecaster knew the history of market prices, whereas the production manager knew the history of his own production decisions and profits. The market clearing price was determined by the production decisions of all firms in the market. Each subject was paid exactly as in treatment 3. Bao et al. (2013) found that most of the subjects used adaptive expectation rule and all the treatments converge to the rational expectations equilibrium, this convergence is fastest and less volatile in the LtFE compared to LtOE treatments.

3. Conclusion

There are several modern macroeconomic theories about how economic agents' expectation varies over a long period of time and how this affects the monetary policy or the other way round is not directly available for all countries. But we have already discussed that this can be easily generated in a laboratory according to the model specification. One important aspect of a macroeconomic experiment is that we can test each part of the theory separately. In the area of experiments of expectation formation literature (LtFE) first have we discussed two equation model (Adam, 2007) then various variation of 3 equation models (Pfajfar and Zakelj (2014), Assenza et al. (2013), Das et al (2013)) which can be considered to be modifications of previous models.

From the above discussion, macroeconomic experiments suggest that heterogeneity is an essential aspect of the theory of expectation formation. Now it is a challenge for theorists to develop a general and reasonable theory of heterogeneous expectations formations, because only a heterogeneous expectations model can explain "observed *path dependence* in the same market environment as well as different aggregate outcomes across different market settings" (Hommes, 2011).

4. Acknowledgement

The authors would like to thank UGC-UPE II (CR and SS) & CAS Economics, and Professor Ajitava RoyChoudhury, Jt. Coordinator and Coordinator of the two programmes respectively, for providing the funds for the study.

5. References

1. Adam, K. (2007),"Experimental Evidence on the Persistence of Output and Inflation", Economic Journal, 117(520), 603-636.
2. Arifovic, J. and T.J. Sargent (2003), "Laboratory Experiments with an Expectational Phillips Curve," in D.E. Altig and B.D. Smith, eds., Evolution and Procedures in Central Banking, (Cambridge: Cambridge University Press), 23-55.
3. Assenza, T., P. Heemeijer, C. Hommes and D. Massaro (2013), "Individual Expectations and Aggregate Macro Behavior," Tinbergen Institute Discussion Paper TI 2013-016/II.
4. Bao, T., J. Duffy and C.H. Hommes (2013), "Learning, Forecasting and Optimizing: An Experimental Study," European Economic Review 61, 186—204.
5. Bernasconi, M. and O. Kirchkamp (2000), "Why Do Monetary Policies Matter? An ExperimentalStudy of Saving and Inflation in an Overlapping Generations Model," Journal of Monetary Economics 46, 315-343.
6. Das, A. (2009), Heterogeneity in Inflation Expectation: An Experimental Economics Approach, M.PhilDissertation, department of Economics, Jadavpur University, India.
7. Das, A., A. Ghosh and G. Gupta (2012),'Expectation Formation in a New Keynesian Model: Evidence from an Experiment", Center for Advanced Studies Working Paper # 07-12, Department of Economics, Jadavpur University, India
8. Duffy, J. (2008), "Experimental Macroeconomics," in: L. Blume and S. Durlauf eds., The New Palgrave Dictionary of Economics, 2nd Ed., (London: Palgrave Macmillan).
9. Duffy, J. and R. Nagel (1997), "On the Robustness of Behavior in Experimental 'Beauty Contest' Games," Economic Journal 107, 1684-1700.
10. Evans, G.W. and S. Honkaphoja (2001), Learning and Expectations in Macroeconomics, (Princeton: Princeton University Press).
11. Garner, C. A. (1982) "Experimental Evidence on the Rationality of Intuitive Forecasters," in Smith, ed. Research in Experimental Economics Volume 2
12. Ho, T., C. Camerer and K. Weigelt (1998), "Iterated Dominance and Iterated Best-Response in Experimental p-Beauty Contests," American Economic Review 88, 947-69.
13. Hommes, C.H. (2011), "The Heterogeneous Expectations Hypothesis: Some Evidence from the Lab," Journal of Economic Dynamics and Control 35, 1—24.

14. Hommes, C.H., J. Sonnemans, J. Tuinstra and H. van de Velden (2005), "Coordination of Expectations in Asset Pricing Experiments" Review of Financial Studies 18, 955-980.
15. Hommes, C.H., J. Sonnemans, J. Tuinstra and H. van de Velden (2007), "Learning in Cobweb Experiments," Macroeconomic Dynamics 11 (Supplement 1), 8—33.
16. Kelley, H., and D. Friedman (2002), "Learning to Forecast Price," Economic Inquiry 40, 556—573
17. Keynes, J.M. (1936), The General Theory of Employment, Interest, and Money, (New York: Harcourt, Brace and Co.).
18. Moulin, Herve (1986), Game Theory for the Social Sciences 2nd ed., (New York: New York University Press).
19. Pfajfar, D. and B. Zakelj (2013), "Inflation Expectations and Monetary Policy Design: Evidence from the Laboratory," working paper, Tilburg University.
20. Nagel, R. (1995), "Unraveling in Guessing Games: An Experimental Study," American Economic Review 85, 1313-1326.
21. Lucas, R.E. Jr. (1972), "Expectations and the Neutrality of Money," Journal of Economic Theory 4, 103-124.
22. Marimon, R., S.E. Spear and S. Sunder (1993), "Expectationally Driven Market Volatility: An Experimental Study," Journal of Economic Theory 61, 74-103.
23. Marimon, R. and S. Sunder (1993), "Indeterminacy of Equilibria in a Hyperinflationary World: Experimental Evidence," Econometrica 61, 1073-1107.
24. Marimon, R. and S. Sunder (1994), "Expectations and Learning under Alternative Monetary Regimes: An Experimental Approach," Economic Theory 4, 131-62.
25. Marimon, R., and S. Sunder (1995), "Does a Constant Money Growth Rule Help Stabilize Inflation?,"
26. Carnegie-Rochester Conference Series on Public Policy 43, 111-156.
27. Muth, J. F. (1961): Rational Expectation and Theory of Price Movements, Econometrica 29, 315-329.
28. Samuelson, P.A. (1958), "An Exact Consumption-Loan Model of Interest With or Without the Social Contrivance of Money," Journal of Political Economy 66, 467-482.
29. Sargent, T.J. (1993), Bounded Rationality in Macroeconomics, (Oxford: Oxford University Press).
30. Sargent, T.J. (1999), The Conquest of American Inflation, (Princeton: Princeton University Press).
31. Schmalensee, R. (1976),An Experimental Study of Expectation Formation, Econometrica, 44(1), 17-41.
32. Smith, V.L., G.L. Suchanek and A.W. Williams (1988), "Bubbles, Crashes, and Endogenous Expectations in Experimental Spot Asset Markets," Econometrica 56, 1119-51.
33. Williams, A.W. (1987), "The Formation of Price Forecasts in Experimental Markets," Journal of Money, Credit and Banking 19, 1-18.