Experimental Macroeconomics*

John Duffy
Department of Economics
University of Pittsburgh
Pittsburgh, PA 15260 USA
Email: jduffy@pitt.edu

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1 Introduction

Experimental macroeconomics is a subfield of experimental economics that makes use of controlled laboratory methods to understand aggregate economic phenomena and to test the specific assumptions and predictions of macroeconomic models. Surveys of experimental macroeconomics are found in Ochs (1995), Duffy (1998) and Ricciuti (2004). Macroeconomic topics that have been studied in the laboratory include convergence to Walrasian competitive equilibrium [Lian and Plott (1998)], growth and development [Lei and Noussair (2003), Capra et al. (2005)], specialization and trade [Noussair et al. (1995)], Keynesian coordination failures [Cooper (1999), Van Huyck et al. 1990], the use of money as a medium of exchange [Brown (1996), Duffy and Ochs (1999, 2002)] and as a store of value [McCabe (1989), Lim et al. (1994), Marimon and Sunder (1993, 1994)], exchange rate determination [Arifovic (1996), Noussair et al. (1997)], money illusion [Fehr and Tyran (2001)], asset price bubbles and crashes [Smith et al. (1988), Lei et al. (2001), Hommes et al. (2005)] sunspots [Spear et al. (1993), Duffy and Fisher (2005)], bank runs [Schotter and Yorulmazer (2003), Garratt and Keister (2005)], contagions [Corbae and Duffy (2005)], speculative currency attacks [Heinemann et al. (2003)], and the economic impact of various fiscal and monetary policies [Riedl and Van Winden (2001), Arifovic and Sargent (2003), Marimon and Sunder (1994), Bernasconi and Kirchkamp (2000)].

The use of laboratory experiments, involving small groups of subjects interacting with one another for short periods of time, to analyze aggregate, economy-wide phenomena or to test macroeconomic model predictions or assumptions might be met with some skepticism. However, there are many insights to be gained from controlled laboratory experimentation that cannot be obtained using standard macroeconometric approaches, i.e., econometric analyses of the macroeconomic data reported by government agencies. Often the data most relevant to testing a macroeconomic model are simply unavailable. There may also be identification, endogeneity and equilibrium selection issues that cannot be satisfactorily addressed using econometric methods. Indeed, Robert Lucas (1986) was the first macroeconomist to make such observations and he invited laboratory tests

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of rational expectations macroeconomic models; much of the subsequent experimental macroeconomics literature may be viewed as a response to Lucas's (1986) invitation. It is also worth noting that experimental methodologies have been improbably applied to the study of many other aggregate phenomena including astronomy, epidemiology, evolution, meteorology, political science and sociology.

2 Insights from Macroeconomic Experiments

To date, experimental macroeconomics research has yielded some important insights, including an understanding of when equilibration works, when it fails, and the means by which equilibrium selection or coordination problems are resolved.

Equilibration, the process by which competitive equilibrium is achieved, is often ignored by modern macroeconomic modelers who typically assume that market-clearing is friction-free and instantaneous. Experimentalists, following the lead of Smith (1962), have explored mechanisms such as the double auction, the availability of information, futures markets and other means by which this equilibration might be achieved or enhanced — see, e.g., Forsythe et al. (1982), Plott and Sunder (1982), Sunder (1995) for partial equilibrium approaches and Lian and Plott (1998) for a general equilibrium approach. A general finding is that, with enough trading experience and information feedback about transaction prices, bids, and asks, even small populations of 5-10 subjects can learn to trade at prices and achieve efficiency consistent with competitive equilibrium in a large class of market environments. Indeed, the institutional rules, e.g., of the double auction, may be all that is necessary to assure equilibration, as shown in the zero-intelligence trader approach of Gode and Sunder (1993).

Experimental insights regarding equilibration have enabled experimentalists to design market environments where equilibration may fail to obtain; in its place are observed price bubbles and crashes [Smith et al. (1988), Lei et al. (2001), Hommes et al. (2005)]. Explaining these laboratory asset price bubbles has proved challenging. Lei et al. (2001) show that speculative motives alone cannot explain bubble formation and suggest that it may have more to do with subject boredom. Duffy and Ünver (2006) suggest that anchoring effects may factor in subjects' bidding up of prices until binding budget constraints force a crash. A further puzzle is that experienced subjects in laboratory asset markets learn to avoid price bubbles and crashes, and generally price assets in line with fundamental values. An explanation for why bubbles and crashes occur among inexperienced but not experienced subjects has yet to be provided. Experiments with mixtures of experienced and inexperienced subjects show no tendency for bubbles to arise [Dufwenberg et al. (2005)].

In environments with multiple equilibria, theory is typically silent as to which equilibrium agents will select or whether there will be transitions between equilibria. Understanding how agents coordinate on an equilibrium is of great interest to macroeconomists, as coordination problems are thought to play an important role in the persistence of business cycle fluctuations. Experimental evidence can and has been used to address the issue of which, among multiple equilibria, is most likely to be achieved, and why.

For instance, Van Huyck et al. (1990) have shown how minimum effort, team production payoff functions can lead to Keynes-type coordination failures – i.e., coordination by groups of subjects on Pareto inferior equilibria. Such inefficiencies do not arise from conflicting objectives or from asymmetries of information; rather, they arise from individual's *strategic uncertainty* with regard to the actions of other market participants. Similarly, Duffy and Ochs (1999, 2002) report

that subjects have no difficulty coordinating on efficient monetary exchange equilibria in Kiyotaki-Wright-type money-search models when theory calls for the use of fundamental, cost-minimizing strategies, but subjects have much greater difficulty coordinating on efficient monetary equilibria that require them to employ more costly and forward-looking, speculative strategies, due perhaps to the unwillingness of other subjects to adopt those same speculative strategies.

Not all of the experimental evidence points to inefficiencies in macro-coordination problems. Marimon and Sunder (1993) show that when subjects are presented with a Laffer-curve-type trade-off between two inflation rates, the efficient, low inflation equilibria is more likely to be selected than is the inefficient, high inflation equilibrium. They show that the low inflation equilibrium is stable under the adaptive learning dynamics that subjects use whereas the high inflation equilibrium is not. Similarly, Arifovic and Sargent (2003) study behavior in a Kydland-Prescott model of expected inflation-output tradeoffs and find that a majority of subjects acting in the role of central bank are able to choose policies so as to induce subjects, in the role of the public, to coordinate their expectations on the efficient but time-inconsistent Ramsey equilibrium. Still, they report occasional instances of 'backsliding' to the less efficient, time-consistent Nash equilibrium.

Finally, Duffy and Fisher (2005) explore subjects' use of non-fundamental "sunspot" variables as coordination devices in an environment with multiple equilibria. They show that when information is highly centralized, as in a call market, subjects do use realizations of a sunspot variable as a device for coordinating on low or high price equilibria, but that this coordination mechanism may break down when information is more decentralized, as in a double auction, or when the mapping from realizations of the sunspot variable to the action space is unclear.

3 Methodological Issues

Methodologically, macroeconomic experiments typically involve some kind of centralized market-clearing mechanism through which subjects interact with one another, e.g., as buyers or sellers or both. The double auction market mechanism [Friedman and Rust (1991)] is the most commonly used market clearing mechanism, as it allows for continuous information on bids, asks, transaction prices and volume – information which is thought to be critical to rapid equilibration and high levels of allocative efficiency. [Lian and Plott (1998), Noussair et al. (1995, 1997)]. The simultaneous, sealed-bid "call market" version of this mechanism has also been used by some researchers [Cason and Friedman (1997), Duffy and Fisher (2005), Capra et al. (2005)].

Some less centralized market mechanisms have also been used. For instance, Brown (1996), Duffy and Ochs (1999, 2002) study a money-search model in which subjects are randomly paired and may trade goods with one another at a fixed exchange rate. In addition, game-theoretic models are also commonly employed, expecially in studies of coordination failure, contagion and speculative attacks. [Van Huyck et al. (1990), Corbae and Duffy (2005), Heinneman et al. (2003)].

A hallmark of modern macroeconomic modeling is the characterization of the economy using recursive dynamical systems where expectations of future endogenous variables determine current outcomes. Several experimental researchers testing such models have found it useful to separate subjects' forecast decisions from market-trading decisions. For instance, [Marimon and Sunder (1993, 1994, 1995) and Hommes et al. (2005)] elicit subjects' forecasts of next period's price level. Using these individual forecasts, they determine subjects' individual demands for the consumption good in the current period and, as supply is fixed, they simultaneously determine the current period price. Similarly, Adam (2006) elicits forecasts of inflation one and two periods ahead, consistent

with the monetary sticky price model that he investigates; these expectations are then used to determine output and inflation in the current period. Marimon and Sunder (1994) refer to this type of experimental design as a "learning to forecast" framework, which they contrast with a "learning to optimize" framework. Of course, in macroeconomic models, it is assumed that agents are able to both forecast and optimize at the same time.

Many macroeconomic models have representative agents and infinite horizons or an infinity of agents and goods which pose some challenges for laboratory implementation and testing of theoretical predictions. The representative agent assumption has been examined by Noussair and Matheny (2002) and Lei and Noussair (2002). They compare consumption and investment decisions made by individual subjects operating as "representative agent-social planers" in the standard Cass-Koopmans optimal growth framework with the decisions made by groups of subjects who first, trade shares of capital via a double-auction market clearing mechanism and then allocate their income between consumption and investment. They find that the double-auction market mechanism results in allocations that are far closer to the theoretical predictions than are the decisions made by subjects in the representative agent role attempting to solve the optimization problem on their own.

To implement infinite horizons, researchers have adopted two designs. One design, used e.g., by Marimon and Sunder (1993), is to recruit subjects for a fixed period of time but terminate the session early, without advance notice, following the end of some period of play. As Marimon and Sunder use a forward-looking dynamic model, they use the one-step-ahead forecasts made by a subset of subjects who are paid for their forecast accuracy to determine final period allocations. A second design is to introduce a constant small probability, $1 - \delta$, that each period will be the last one played in a sequence, and allow enough time for several indefinite sequences to be played in an experimental session [Duffy and Ochs (1999, 2002), Noussair and Lei (2002), Capra et al. (2005)]. This design has the advantage of inducing both the stationarity associated with an infinite horizon and discounting of future payoffs at rate $(1 - \delta)/\delta$ per period (equivalently a discount *factor* of δ).

Related to the infinite horizon problem, overlapping generations models, as studied by Marimon and Sunder (1993, 1994, 1995) and Marimon et al. (1993) have an infinity of agents (and goods). Marimon and Sunder cope with this difficulty by recycling subjects – allowing each subject to live several two-period lives over the course of an indefinite sequence of periods. Marimon and Sunder (1993) argue that this repeated entry and exit of subjects does not induce any strategic opportunities that are not already present in the overlapping generations model without "rebirth." Indeed, the need for a large number of agents to study macroeconomic behavior is a common issue confronted by researchers. However, results from many double auction experiments suggest that competitive equilibrium can be quickly achieved with as few as 3-5 subjects operating on each side of the market. Similarly, while search-models of money assume a continuum of agents, Duffy and Ochs (2002) argue that the strategic incentives generated by having finite subject populations does not alter the equilibrium predictions of those models under the assumption of a continuum of agents.

Perhaps the most difficult methodological issue is the external validity of macroeconomic experimental findings. While external validity is generally a problem for all experimental economists, it might be regarded as a greater problem for macro–experimentalists seeking to explain economy-wide aggregate macroeconomic phenomena using necessarily small-scale laboratory evidence. Experimental macroeconomists have several responses to this issue. First, as noted earlier, modern macroeconomic models have explicit micro foundations as to how individual agents make decisions

(e.g., agents recognize the relevant trade-offs, form rational expectations) which can be directly tested in the laboratory. Indeed, in the laboratory one can be more certain about micro-level *causal relationships*, i.e., that an experimenter induced change in a variable is the source of any observed change in subject behavior as opposed to some other, unaccounted-for factors. Macroeconometric analyses of field data cannot claim the same degree of *internal validity*. A second response is to make use of highly experienced subjects – those who have participated in the same experiment many times - as a means of better proxying real-world behavior. As noted earlier, asset price bubbles and crashes seem to disappear with experienced subjects. A third response has been to use parametric forms or calibrations of macroeconomic models that are of interest to macroeconomists, or to present subjects with real macroeconomic data as part of the experimental design (e.g., Bernasconi et al. (2004)). Finally, many experimentalists would argue that all experimental work, including macroeconomic experiments should be judged by the findings obtained and not by biases concerning the suitability of laboratory versus other empirical methods, all of which have their strengths and weaknesses.

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