Macroeconomics: A Survey of Laboratory Research
Chapter for the *Handbook of Experimental Economics*, Vol. 2

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Laboratory Macroeconomics?

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- The goal of this summer school: **regime change**.

How to Characterize Experimental Macroeconomics?

- A large number of subjects? No. Most modern macroeconomic models presume a representative agent and do not address aggregation issues.

- In practice, experimental macroeconomics is not distinct from microeconomic laboratory experiments, there is just a different focus or interpretation.

- A macroeconomic experiment as *one that tests the predictions of a macroeconomic model or its assumptions or is framed in the language of macroeconomics*.

- Some novel macroeconomic experimental methodological innovations such as implementation of infinite horizons and discounting, overlapping generations, the representative agent assumption, analysis of the convergence of time series.

Chapter Organization

1. Microfoundations
2. Coordination Problems
3. Sectoral Macroeconomics
4. Macroeconomic Policy

- Parts of this chapter update *Handbook of Experimental Economics* chapters on "Coordination Problems" (Ochs), "Asset Markets" (Sunder) and "Individual Decision Making" (Camerer), though here the focus is on models primarily of interest to macroeconomists.

- The chapter draws on earlier surveys of macroeconomic experiments by Duffy (1998, 2008) and Ricciuti (2008).

1. Microfoundations

Modern macroeconomic models have explicit *microfoundations*. These can be tested in the laboratory:

1. Intertemporal optimization (consumption/savings decisions): Is consumption smoothing observed?
2. Time (in)consistency of intertemporal decisions: exponential vs. hyperbolic discounters or neither?
3. Expectation formation: rational or adaptive or neither?

What about aggregation?

While macroeconomists are aware of the Sonnenshein-Debreu-Mantel result–that the system of excess demand functions characterizing an economy with many agents need not correspond to the demands of the individuals making up that economy–they nevertheless impose the Representative Agent (RA) assumption (Kirman 1992, Fisher 1997). Given this state of affairs, macro-experimentalists have pursued several approaches:

- Take the RA assumption seriously and conduct *individual* decision-making experiments, e.g., on consumption–smoothing.
- The RA assumption implies that there are *no* coordination problems and *no* trade. Both assumptions can be tested in the laboratory.
- Introduce an aggregation mechanism, e.g., double auction markets, to obtain market-clearing prices and quantities.
- Some (typically game- or search-theoretic) "macro" models do have heterogeneous player types and aggregation mechanisms that *are* testable in the lab.

Intertemporal Optimization: Issues and Methods

- Can individuals solve a stochastic, dynamic intertemporal optimization problem?

$$\max_{c_t} E_t \sum_{t=0}^{\infty} \delta^t u(c_t)$$

subject to:

$$c_t + x_t \leq \omega_t$$

where c_t is time t consumption, $u(\cdot)$ is a concave utility function, δ is the period discount factor, x_t represents time t savings and ω_t is the household's wealth.

- Methodologically, laboratory studies have typically
  - used both finite and indefinite horizons.
  - have induced preferences
  - have an exogenous return on savings, no borrowing.
  - have wealth evolve according to $\omega_{t+1} = R(\omega_t - c_t) + y_{t+1}$, with y being a random income draw (or set to zero).

Intertemporal Optimization: Main Findings

- Subjects typically under-save (consume too much) relative to the optimal. Consumption binging is also observed.
- Inconsistent with consumption smoothing, consumption appears dependent on immediate past income realizations. (Hey and Dardoni *EJ* (1988)).
- Some improvement in the direction of the optimal consumption/savings plan with social learning - learning from others/older generations (Ballinger et al. *EJ* 2003).
- Comparative static implications (changes in R, β) finds support for theory (Hey and Carbone *EJ* (2004)).
- Use of double auction market to allocate capital does better than an individual in the role of a social planner. (Lei and Noussair *AER* (2002)).
- Adding an internal habit formation incentive may induce agents to save more early and get them closer to the optimal path (Brown et al. *QJE* (2009))

Discounting and Infinite Horizons: Methods

- Most macroeconomic models assume infinite horizons. Bequest motives are assumed operative so individuals are viewed as part of a family dynasty.

- Exponential discounting.

- Methodologically both are implemented by having a constant probability δ with which a sequence of decision rounds continues with one more round. This implements both discounting by factor δ and the stationarity associated with an infinite horizon.

- In practice, it is good to 1) have multiple indefinite sequences in a session (so as to properly induce discounting of payoffs) and 2) recruit subjects for enough time to allow the experiment to end naturally (also requires a good choice for δ) and provision for the case in which it does not do so in the time allotted for the experimental session. 3) Use a transparent randomization device.

Discounting: Exponential Findings

- Evidence from indefinitely repeated Prisoner's Dilemma experiments that cooperation rates increases with increases in the exponential discount factor (e.g., Dal Bo (2005)).
- Elicitation of rates of time preference (discount rates) is achieved by asking subjects to choose between pairs of delayed monetary rewards, e.g., amount D in 2 days or $D(1+r)$, in $2+t$ days, where $r > 0$ is fixed and t is incrementally increased, $t = 1, 2, ..$ Any subject with a positive discount rate will eventually switch.
- The time t^* at which a subject permanently switches from the larger amount, $D(1+r)$, to the smaller amount, D, is used to solve for their discount factor $\delta_i : \delta_i^{t^*} = 1/(1+r)$ (assumes linear utility from money).
- There are no consistent estimates of discount rates across many studies (Frederick et al. (2002)).
- Time preferences cannot really be elicited apart from risk preferences (above we assumed risk-neutrality). See Anderson et al. (2008).

Discounting: Exponential of Hyperbolic?

Quasi-hyperbolic discounting: Representative agent maximizes

$$u(c_t) + \beta \sum_{i=1}^{T} \delta^i u(c_{t+i}),$$

where $\beta \leq 1$ characterizes the agent's bias–for–the–present (exponential discounting has $\beta = 1$).

Experimental evidence on this form of discounting is mixed but evidence for exponential discounting appears to be soundly rejected.

E.g. Benhabib et al (2010) and Coller et al. (2006) find that a small fixed premium attached to immediate rewards, can reconcile much of the variation in discount rates between the present and the future and between different future rewards. This premium does not vary with the amount of future rewards (Benhabib et al.) and may simply reflect transaction/credibility costs associated with receiving delayed rewards (Coller et al.).

Expectation Formation: Methods

- In modern, self-referential macroeconomic models, expectations of future endogenous variables x, play a critical role determining current endogenous variables, e.g., $x_t = f(x_{t+1}^e)$.
- Agents are assumed to have rational, (model-consistent) expectations.
- Early experiments found evidence of non-rational expectations in the sense that forecast errors are systematic. Some researchers used exogenous data generating processes: Schmalensee (1976) or Dwyer et al. (1993). Others test for rational expectations using data determined by the action choices of subjects themselves: Williams (1987), Smith et al. (1988).
- Marimon and Sunder (1993, 1994) pioneered a "learning-to-forecast" design where subjects just form expectations of future (date $t+1$) endogenous variables which are then used to compute their optimal, date t choices. Subjects are rewarded based on forecast accuracy alone. This design facilitates formation of rational expectations by getting rid of optimization! Hommes (2011) surveys this literature.

Boundedly Rational Expectation Formation

Some macroeconomists have replaced the rational expectations assumption with boundedly rational expectation formation processes that converge to rational expectations in the limit, following many repetitions:

1. Step-level or level-k reasoning imagines that players are heterogenous in their abilities to iterate their way toward a rational expectations equilibrium. The lowest type, L_0, make purely random choices. The next higher level L_1, players play "best responses" to the behavior of the L_0 types. Level L_2 players play "best responses" to the L_1 types, etc. This is reminiscent of Keynes's (1936) comparison of financial market investor's expectations to newspaper beauty contests.

2. Adaptive (recursive least squares or gradient) learning approaches to expectation formation, e.g., Sargent (1993, 1999) Evans and Honkapohja (2001) imagine that agents behave as though they were econometricians, forming expectations using the historical data record, and updating these expectations in real time as new data become available.

Boundedly Rational Expectation Formation: Findings

- Step-level analyses of behavior in the p-Beauty contest game (Nagel (1995)) provides both evidence against rational expectations in the short-run and in favor of heuristic, step-level reasoning. Level types above level 2 are rarely observed (a robust finding).

- Hommes et al. (2007, 2005) use a forecasting game to study learning dynamics in the Cobweb (hog cycle model). They vary the stability of the cobweb model under the assumption of naive expectations (following the classic analysis of Ezekiel (1938)) and find that subjects learn the rational expectations price level regardless of the stability condition, but there is higher variance as the model is made more unstable.

- In experiments using forward-looking New Keynesian models, Adam (2007) finds that inflation cycles about its steady state and argues that subjects may have coordinated on non-REE "restricted perceptions" equilibria. Pfajfar and Santoro (2010) argue that this cyclicality in inflation is due to heterogeneity in subjects' inflation forecast rules.

2. Coordination Problems

Why are these of interest to macroeconomists?

- Fallacies of composition - individual pursuit of self-interest may have adverse aggregate consequences.
  - Keynes' paradox of thrift - everyone saving more during a recession, reduces aggregate demand, which leads to lower total savings in the population (maybe not in general eq.)
  - Friedman's critique of individual desires for cheap money policies - they lead to inflation.

- Representative agent assumption may mask considerable heterogeneity in behavior, which may itself present a coordination problem, e.g. if some individuals are rational and far-sighted while others are myopic, how to behave (e.g. ride a bubble or pop it?)

- Even with perfectly rational agents, macroeconomic models often give rise to multiple equilibria that theory cannot resolve. In such situations, Lucas (1986) famously proposed putting people in the lab and "seeing what they do."

'Macro' Coordination Games

- Simple, large N-player order-statistic games where under rational expectations, there are multiple, Pareto rankable equilibria.
- Payoff function is given by: $\pi_i = f(X - |e_i - X|)$ where X is an order statistic, e.g., the minimum or the median, and e_i is an ordered set of choices, (e.g., effort levels).
- Example: Van Huyck et al.'s (1990) minimum effort game:

$X = \min\{e_1, e_2, ..., e_N\}$

$e_i \setminus X$	7	6	5	4	3	2	1
7	1.3	1.1	.90	.70	.50	.30	.10
6		1.2	1.0	.80	.60	.40	.20
5			1.1	.90	.70	.50	.30
4				1.0	.80	.60	.40
3					.90	.70	.50
2						.80	.60
1							.70

- How would you play it?

Coordination Problems: Models and Potential Solutions

1. Poverty traps: Escape from an inefficient low growth to a high growth equilibrium?

2. Bank runs: Transition from a efficient equilibrium involving financial intermediation to an inefficient panic equilibrium?

3. Mechanisms for solving coordination problems: Nonfundamentals - sunspots (a.k.a. animal spirits, self-fulfilling prophecies)

4. Mechanisms for solving coordination problems: Fundamentals - the global game refinement.

Poverty Traps

- Lei and Noussair (2003), Capra et al. (2009) add a non-convexity in production to the one-sector optimal growth model yielding two Pareto rankable stable, stationary levels for the capital stock (and output) $\overline{k}_l < k^* < \overline{k}_h$, $k^* = 31$.

- Lei and Noussair start subjects above or below k^* and in a decentralized setting or as social planners. They find that the poverty trap is the attractor in the decentralized setting while social planners coordinate on capital stocks near k^* or to the golden-rule level that maximally equates consumption in every period.
- Capra et al. start subjects below k^* and examine whether voting and/or communication can move economies out of poverty traps.

Bank Runs

- Diamond and Dybvig's (1983) bank run model has an efficient separating equilibria, where patient types wait to withdraw funds and impatient types withdraw early and an inefficient pooling (panic) equilibrium where both types withdraw early and the bank must liquidate its long-term investments.

- Garratt and Keister (2009) study the following bank-run game with 5 depositors and 1-3 withdrawal opportunities:

No. of Early Withdrawal Requests	Amount Each Early Requester Receives	Payment to Each Who Don't Withdraw
0	n/a	$1.50
1	$1	$1.50
2	$1	$1.50
3	$1	$0
4	$0.75	$0
5	$0.60	n/a

- Panic equilibrium only arises if there are liquidity shocks: 1 (unknown) subject is randomly forced to withdraw early.

Sunspots

- Sunspots are non-fundamental variables that may serve as a coordinating device. Sunspots were traditionally used to explain the onset of panic equilibria in Diamond and Dybvig's (1983) bank-run model. Keynes (1936), Akerlof and Shiller (2009) refer instead to 'animal spirits'.

- Marimon et al. (1993) hoped subjects might use a blinking light that alternated in color between red and yellow as a mechanism for coordinating price forecasts on a cyclic equilibrium in an OG economy. When correlation with fundamental shocks was removed, subjects essentially ignored the sunspot variable realizations and coordinated on a stationary outcome.

- Duffy and Fisher (2005) found that subjects would coordinate on spurious public forecasts for prices (determined by flipping a coin) provided that no other information was available–when prices were determined in a highly centralized "call" market. However, if prices were determined in a double auction, the efficacy of the sunspot variable as a coordination device was much reduced.

Global Game Refinement

- A more recent view of multiple macro equilibria is that the equilibrium beliefs in support of these equilibria may not be indeterminate. As Morris and Shin (1998, 2001) argue, indeterminacies arise from assuming that economic fundamentals are common knowledge and that individuals are certain of the behavior of others in equilibrium.

- Relaxing these assumptions, e.g. by introducing some uncertainty about fundamentals, can remove the multiplicity, á la the Carlsson and van Damme's (1993) global game approach for 2×2 games. This proposed refinement has been tested experimentally by Heinemann et al. (2004) in the context of a $2 \times n$ player speculative currency attack game with multiple equilibria. Also Cabrales et al. (2007), Costain et al. 2007, Duffy and Ochs (2010).

- Heinemann et al. report that subjects play the game of complete information similarly to the way they play a global game of incomplete information. Consistent with the global game refinement, they adopt threshold strategies attacking only when fundamentals are sufficiently weak and not attacking otherwise.

3. Sectoral Macroeconomics: Monetary Economics

Money's three roles have been studied experimentally:

- As a store of value. Money may have value in use even with a finite horizon (McCabe (1989)). Money may serve as an intertemporal store of value among overlapping generations of agents (with no other means of savings) and low (as opposed to explosive or high) inflationary equilibria are typically chosen by subjects. Lim et al. (1994), Marimon and Sunder (1993, 1994 1995), Bernasconi and Kirchkamp (2000), Camera et al. (2003), Deck et al. (2006).
- As a medium of exchange. Worthless or low cost objects serve as media of exchange in a search-theoretic models where there is an absence of double-coincidence of wants. Brown (1996), Duffy and Ochs (1999, 2002), Camera and Casari (2011), Duffy and Puzzello (2011).
- As a unit of account. Individuals are subject to money illusion, thinking in nominal rather than real terms. (Diamond et al. (1997), Fehr and Tyran (2001, 2007, 2008).

3. Sectoral Macroeconomics: Labor Economics

- Search theoretic models - support for comparative static implications of optimal job search (Braunstein and Schotter (1981, 1982) for an infinite horizon, Cox and Oaxaca (1989, 1992) Sonnemans (1998) for a finite horizon.

- Labor-leisure tradeoffs: wage increases have both income and substitution effects on hours worked. Battalio et al. (1981) and Dickinson (1999) report evidence that the (compensated) elasticity of labor supply to a wage increase is positive, in accordance with the assumption made in most business cycle models.

- Efficiency wage theory (Shapiro and Stiglitz (1984), Akerlof (1982)): Higher than market wages are reciprocated with high effort . Ernst Fehr and associates show in several papers that if workers outnumber firms/positions, and firms offer high wages, reciprocity considerations can lead to high effort levels exerted by subjects playing the role of workers.

Gift Exchange Game: Incompleteness of Labor Contracts

- Fehr, Kirchsteiger and Riedl (1993, 1998), Gächter and Fehr (2002).
- Subjects as firms or workers, # firms < # workers.
- Firms can hire at most one worker and move first, posting wage offers $w \in [\underline{w}, \overline{w}]$. If a worker accepts a wage offer, they then choose an effort level $e \in [\underline{e} \ \overline{e}]$.
- Payoffs to workers are $w - c(e)$, where $c(e)$ is a convex cost of effort function. Payoffs to firms are $(v - w)e$ where v is the firm's redemption value. All payoff functions, wage and cost of effort schedules were public knowledge.
- Interactions are repeated, but anonymous, (so one-shot?) The subgame perfect equilibrium prediction is that workers will choose the lowest possible effort level $\underline{e}$ and recognizing this, firms will offer the lowest possible wage $\underline{w}$.
- Experimental finding is that high wage offers lead to high effort: Players have preferences for fairness/reciprocity.
- See Healy (2007) for an argument based on folk theorems for finitely repeated games.

3. Sectoral Macroeconomics: International

- Trade theory
- Noussair et al. (1995) test the law of comparative advantage in a model with two countries, 1 and 2 with two final goods, Y and Z. The countries differ only in their production technologies, which (in the Ricardian version) involve only labor input L_i from country $i = 1, 2$.

Country 1	$Y_1 = 3L_1$	$Z_1 = L_1$
Country 2	$Y_2 = L_1$,	$Z_2 = 2L_2$

- Labor is immobile across countries but trade in goods is possible.
- Six markets - two internal labor markets and four final goods markets are implemented using double auctions.
- The comparative advantage prediction, wherein country 1 specializes in production of good Y and country 2 specializes in production of good Z is confirmed.

International Finance

- Purchasing power parity and exchange rate determination have been studied experimentally using two-country models.
- Noussair et al. (1997) use a two country model with two different money supplies, introduced via cash-in-advance constraints. They study whether purchasing power parity holds.
- Fisher (2001, 2005) provides a simpler framework in which to address purchasing power parity as well as (un)covered interest parity.
- Arifovic (1996) Considers a two-county overlapping generations models where there are no cash-in-advance constraints and the monies of the two countries are perfect substitutes for one another. She addresses the indeterminacy of the exchange rate issue, and finds that exchange rates do appear to converge, but fluctuations persist, consistent with what is seen in actual time series data.

The Big Picture: Multi-sectoral Systems

Lian and Plot (*ET* 1998) consider an environment with double auction markets, where there are workers and firms, two goods (X,Y), money and bonds, workers seek to maximize preferences over (X,Y) and sell labor Y to firms for money; firms seek to maximize output of X using labor input, which they then sell for money. Generally, efficiency is high. A novelty is that such an exercise can be performed at all!

Macroeconomic Policy Issues

- Ricardian Equivalence: Cadsby and Frank (1991) use an overlapping generations model with bequests and find that bequests are close to optimal(!), but changes in bequests do not fully offset changes in government debt. See also Di Laurea and Ricciuti (2003).
- Commitment versus Discretion:
  - Peasant-dictator games: Peasants decide whether to consume or plant beans. Planting beans yields a harvest of more beans, which is subject to taxation by the dictator (immediate consumption is not). Van Huyck et al. (2001) show that a dictator's reputation for low taxes in a repeated game setting serves as a poor substitute for commitment (pre-announced tax rates), but improves upon pure discretion, choosing tax rates after beans are planted.
  - Absent any ability to commit, can policy-makers *learn* optimal policy? Arifovic and Sargent (2003) induce a Kydland-Prescott environment with an expectational Phillips curve and show than subjects in the role of the central bank imperfectly achieve an optimal Ramsey (commitment) equilibrium involving zero inflation.

Monetary and Fiscal Policies

- Monetary Policy Decisions: Blinder and Morgan (2005, 2007, 2008) and Lombardelli et al. (2005) show that the decisions of monetary policy *committees* outperform those of individuals. Engle-Warnick and Turdaliev (2010) show that subjects learn to control inflation/output in a manner that resembles a Taylor rule.
- Bernasconi et al. (2006) explore how subjects form expectations about fiscal variables, e.g., government expenditure levels and tax revenues. Answer: Very adaptively, with great weight placed on recent forecast errors.
- Riedl and van Winden (2001,2007) explore government tax policies concerning the financing of unemployment benefits. Specifically, they consider the impact on unemployment of a constant unemployment benefits tax that, in equilibrium results in a balanced budget, versus a dynamic tax policy that only gradually closes any budget deficit. They find that the dynamic policy leads to a worse outcome than does the stable tax policy.

Political Economy: Redistributive Policies

- van der Hiejeden et a. (1998) hypothesize that social security systems involving transfers from young to old are sustained by a grim trigger strategy in which a failure of any young generation to transfer funds to the old would revert to a perpetual punishment of no further transfers. They find that voluntary transfers from young to old do occur, but, inconsistent with their hypothesis, these transfers not depend on whether such transfers can be monitored or not.

- Cabrales et al. (2006) study whether an efficient, redistributive contract from rich to poor can emerge in the laboratory in the presence of heterogenous income and a variety of voting rules. Their main finding is that such redistributive contracts are unlikely to emerge.

What is Left to Do?

- Borrowing constraints, collateral constraints in intertemporal decision-making.
- Endogenous growth models, e.g. AK models, or models with knowledge externalities due to human capital accumulation.
- Political economy models of debt and deficits: is there a political business cycle? Stability of monetary unions?
- Sources of sticky price adjustment: is it menu costs, sticky information or learning/bounded rationality?
- Labor market search in models that embed the individual, decision-theoretic model into a more general equilibrium framework.
- Monetary policy rules: which is most effective at controlling inflation: money supply or interest rate rules? (Friedman, Inflation targeting, Taylor rules).
- Social security: welfare consequences of pay-as-you-go versus fully funded systems.