Expectations and the Nonneutrality of Lucas

Long before rational expectations, macroeconomists interpreted time series of aggregate quantities, monetary and fiscal variables, and nominal price levels in ways designed to inform macroeconomic policy decisions. By imposing more stringent standards of internal consistency, the 'rational expectations movement' caused substantial reformulations of policy questions and down sizing of the models we believe to be workable.

Equilibrium macroeconomics continues 'M.I.T. economics' in the ways it uses small but self-consistent 'parable' economies to confront broad facts. From the beginning, Solow's one-sector growth model and his growth residual and Samuelson's overlapping generations model were the vehicles that drove rational expectations revolutionaries to the front. Many of us regard Lucas's 1972 JET paper as the flagship of the Revolution; it is different than the flagship of that earlier revolution, Keynes's *General Theory of Employment, Interest, and Money*, which was ambitious, wide-ranging, imprecise, and vague enough to induce twenty-five years of controversy about what the book really meant. Lucas's paper was a narrow, technical study of a modification of Samuelson's parable economy, designed to be a counterexample to interpreting a negative unemployment-inflation correlation as something that a particular type of monetary *cum* fiscal policy could exploit. There was never any confusion about what Lucas's paper meant, any more than there was about Samuelson's or Solow's. If Lucas's paper was slow reading for macroeconomists, it was because we were unfamiliar with contraction mappings, and with thinking of equilibria as *functions*.

It extends our appreciation of Lucas's contributions to remember that he did not work in a vacuum, and that among his many gifts is the ability to demonstrate by choice of engaging examples the importance for macroeconomic policy questions of making pre-existing ideas fit together.

The Late 60's

The late 1960's were good times to be a young macroeconomist. The stage had been set for general equilibrium models by the triumph of simultaneous equations as the language both for building theoretical models and for estimating them. Modigliani, Metzler, and Tobin had used small systems of simultaneous equations to pose and clarify a variety of macroeconomic issues, a development that represented real progress over the loose verbal discussions that had preceded Hicks's 'Keynes and the Classics.' The Cowles Commission methodology had an immense impact on macroeconomics, by insisting on estimation procedures that respected a model's complete stochastic specification.

By the late 60's, macroeconomic models were influential, big, and econometrically advanced. They incorporated increasingly sophisticated dynamics and attracted the efforts of the best economists. The air was charged with new ideas about distributed lags, costs of adjustment, adaptive and rational expectations, the expectations theory of the term structure, 'efficient markets' theories of asset prices, portfolio theories of asset demand, the natural rate of unemployment, and the optimum quantity of money. Monetarism was at high tide. Two competing visions for macroeconomics articulated by Tobin and Friedman dominated conversation. Tobin applied insights from portfolio theory to probe beyond demand curves for monetary aggregates, and had taken important steps toward formulating Modigliani-Miller theorems for open market operations. Friedman and his students had pioneered the use of distributed lags in macroeconomic contexts. Friedman had shown how replacing current income with permanent income, modeled as a geometric distributed lag of actual income, as an argument in the consumption function would lower pure deficit fiscal policy multipliers, and how as an argument in the demand for money, permanent income would raise short-term money multipliers. Friedman and Meiselman ignited a storm about appropriate ways of interpreting distributed lags and verifying econometric exogeneity for money and income. Jorgenson's (1963) work on investment responded to Haavelmo's (1960) challenge and formulated a neoclassical investment theory that restricted distributed lag regression equations. Nerlove (1969) initiated the process of using Whittle's (1963) work on classical linear least squares forecasting to interpret distributed lags. Optimal control theory was being applied both to formulate optimal monetary and macroeconomic policy rules, and to study dynamic demands for factors of production.

Though no one knew how these things fit together, a feeling was abroad that they should.[1] At the AEA meetings in 1966, Dale Jorgenson discussed Miguel Sidrauski's paper about the optimum quantity of money and asked why, in Sidrauski's dynamic model, there appeared three distinct prices for money: its value in exchange, the (rate of change of its) expected future value, and a shadow price of money. Wouldn't a consistent presentation of the theory equate these prices? It would take seven years before Brock (1973) reconciled Sidrauski's three prices.

Sidrauski and Jorgenson's exchange represented advanced thinking of the time, and showed how close the best macroeconomists were to formulating and using a *rational expectations* equilibrium. Muth's (1961) paper had been widely read and admired, but it had not been understood well enough to apply in macroeconomic and monetary contexts. Maybe that was because Muth framed his analysis in terms of objects from the classical literature on forecasting time series unfamiliar to most macroeconomists.[2]

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[1] From the start there was a tension within the American Keynesian Tradition with its emphasis on building comprehensive macroeconomic models, because their sheer size spawned a decentralized research strategy (with increasing subdivision of labor by sector and equation) that worked against things fitting together.

[2] Most of us were inadequately trained. In a 1971 meeting at the Minneapolis Fed, Neil Wallace and I tried to convince Thomas Muench that an infinite regress problem

In several papers in the early 1970's, Brock, Lucas, and Prescott formalized and extended the concept of a rational expectation equilibrium, showed how to apply recursive methods to build equilibria, and carefully selected important substantive examples that proved the power of the equilibrium concept. These papers set us on a path that transformed macroeconomics. They thrust it toward a pre-determined destiny: it would be inconceivable for macroeconomics nowadays *not* to use the same equilibrium concepts (Nash or competitive) used in all other applied fields.

Origins: 'Theory of Value,' O.G., and Cass-Koopmans

General equilibrium theory was systematized in Debreu's *Theory of Value* in 1958. Before 1970, most macroeconomists did not regard Debreu's book as affecting them. By the end of the 1970's, Debreu's book had a place at the center of macroeconomics in various senses: as a *standard* of internal consistency and first principles (individual optimization in the context of a coherent physical environment); as a serious positive model of business cycles; as point of departure for 'missing links' models of monetary economies.

In 1970, relative to their knowledge of general equilibrium theory, macroeconomists were a little more familiar with growth theory. Koopmans (1965) and Cass (1965) converted Solow's (1956) growth model into a theory of optimum growth in a command economy. Koopmans's and Cass's conversion of the Solow model stands as a microcosm of the 'rational expectations' revolution about to occur. Koopmans and Cass removed the Keynesian consumption function and replaced it with an intertemporal utility functional ordering consumption paths.

Cass and Koopmans' model is a unified and consistent theory of consumption and investment; *Theory of Value* is a whole *class* of theories of consumption and investment. Before 1970, there was little understanding about how those theories of consumption and investment fit together with theories about the same subjects developed by macroeconomists, or how they could be applied empirically. During the 1970's, understanding would grow into an enthusiasm among macroeconomists for putting both Cass and Koopmans and Debreu to work.

Paul Samuelson's and Peter Diamond's overlapping generations models form a third source. Samuelson's stationary equilibrium with valued fiat currency is a perfect foresight equilibrium and Lucas's point of departure. In that stationary equilibrium, the institution of fiat currency cures the Pareto sub-optimality that would prevail without it, because money changes hands

would render it impossible to construct a macroeconomic model along the lines of Tobin's 1955 'Dynamic Macroeconomic Model' which attributed to investors correct knowledge of *all* derivatives of the price level. I recall how I didn't know what to make of Muench's innocent query: 'Have either of you heard about fixed point theorems being applied to differential equations?' We hadn't, and neither had we understood how to adapt Grunberg and Modigliani's (1954) argument. A few years later, Robert Townsend (1983) would solve a harder infinite regress 'problem.'

over time to facilitate trades that would not occur in its absence. By adding production and capital accumulation, Diamond created a structure for characterizing situations in which a permanent government debt could cure 'capital overaccumulation.'

The Rational Expectations Revolution

The 'rational expectations revolution' promoted the practical application to macroeconomic times series of an equilibrium concept consistently incorporating individual rationality. What popularized the revolution was not the set of more general theoretical papers by Lucas, Prescott, and Brock but a small set of applied papers focusing on topical macroeconomic examples that indicated the *difference* a rational expectations equilibrium concept could make. Three key papers by Robert E. Lucas's 'Expectations and the Neutrality of Money' (1972), AEA (1973), and 'Econometric Policy Evaluation: A Critique' convinced us that rational expectations would require substantial adjustments in our modeling strategies, and would deliver substantially different theoretical outcomes.

It took us longer than we like to recall to understand how thoroughly the idea of rational expectations would cause us to change the way we did macroeconomics. Neil Wallace and I had already written several papers about rational expectations in 1969–1972, and had read drafts of Lucas's JET paper as well as two key papers by Lucas and Prescott. But we didn't understand what was going on until, upon reading Lucas's 'Econometric Policy Evaluation' in Spring of 1973, we were stunned into terminating our long standing Minneapolis Fed research project to design, estimate and optimally control a Keynesian macroeconometric model.[3] We realized then that Kareken, Muench, and Wallace's (1973) defense of the 'look-at-everything' feedback rule for monetary policy – which was thoroughly based on 'best responses' for the monetary authority exploiting a 'no response' private sector – could not be the foundation of a sensible research program, but was better viewed as a memorial plaque to the Keynesian tradition in which we had been trained to work.

Lucas's JET paper formulated a version of Friedman and Phelps' natural rate theory that was consistent with the new equilibrium concept, and displaced the older distinction between short and long runs in favor of one between expected and unexpected outcomes. The power of that paper resides in the ways it mixes respect for previous work (on the quantity theory of money, the Phillips curve, the natural rate hypothesis, proposals for a constant growth

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[3] I played an essential role in bringing to life Lucas's 'Econometric Policy Evaluation,' which Lucas has never publicly acknowledged. On a Friday early in April 1973, I organized a small conference on rational expectations at Ford Hall at the University of Minnesota. On Saturday morning, I received a phone call from Rita Lucas relaying a request from Bob, who was playing baseball, that I return to Ford Hall to search for an important folder Bob had misplaced. I found a file containing a handwritten draft of 'Econometric Policy Evaluation' and mailed it to Bob.

rate of money) with shrewd analytical choices (combining Samuelson's overlapping generations structure with Phelps's islands, explicit randomness, and the rational expectations equilibrium concept) to make sharp new statements about empirical work and the design of counter cyclical government policies.

Lucas's model environment had many features that provoked further useful research, including (a) the existence of equilibria outside the class to which Lucas restricted attention; (b) other monetary-fiscal policies; (c) alternative social welfare functions for ranking alternative policies.

The East Coast

The JET paper, and the papers by Lucas and Prescott, Brock, and Brock and Mirman, are the origins of research programs spanning broad areas of macroeconomics and economic dynamics. From today's standpoint, it is evident that the rational expectations revolution was impartial in the rough treatment it handed out to participants on both sides of the monetarist-Keynesian controversies raging in the 1960's, and it is puzzling to comprehend the reluctance with which many leading Keynesian economists initially greeted rational expectations methods. There was much in the rational expectations program that Keynesians should have welcomed,[4] but if we re-enter the mind set of 1960's macroeconomics, we can understand the Keynesian establishment's initial reactions to rational expectations.

In the 1960's, the Keynesians surely held the technical high ground in macroeconomics. The best Keynesians cast their arguments in terms of econometrically estimable, structurally interpretable systems of stochastic difference equations, and discussed policy by applying optimal control techniques to those systems. While Keynesians enthusiastically embraced the Cowles Commission simultaneous equations methods, Friedman and his followers refused to use that framework or language.[5] Throughout the 1960's, leading Keynesians criticized Milton Friedman for not explicitly writing down the macroeconomic model that guided his data interpretations.[6,7] Samuelson and Tobin alluded to principles of optimal control to argue for a 'look at everything rule' for monetary policy, and chided Friedman for not rigorously defending his advocacy of a constant growth rate rule. Friedman's writings were filled with insightful remarks and potshots at Keynesians structures, but lacked a theoretical or statistical structure approaching the comprehensiveness and consistency of Keynesian structures.

With the publication of Lucas's JET paper and Sims's AER paper on money and income, Keynesians lost the technical high ground, and were never to recover it. From a methodological point of view – Tobin was the person

[4] Recall the issues about the relative potency of monetary and fiscal policies at the heart of the debate between Walter Heller and Milton Friedman (1968).

[5] See Friedman's footnote on the identification problem ... in *Essays in Positive Economics.*

[6] See Tobin's review of the Monetary History in the AER, 1962.

[7] Friedman eventually responded by producing his 'Framework,' which looked disappointingly like an IS-LM model.

best positioned to recognize this – the monetarist messages carried by Lucas's JET paper were incidental and in some ways fragile. Lucas had to set things up very carefully to attain his neutrality result, by imposing a narrow class of monetary-cum-fiscal policies; neutrality would not carry over to 'open-market' operations as usually defined. Nevertheless, Lucas's paper exhibited the first rigorous example of an economy for which Friedman's $k-$percent rule could not be dominated, exhibited how to use the rational expectations equilibrium concept, and raised questions about econometric identifiability destined to undermine the ways Keynesians had come to implement Cowles Commission methods.

For better or worse, the best young scholars are always attracted to the technical high ground, and it was the technical superiority of Keynesian economics in the 1960's that attracted the best young American macroeconomists. The loyalty of those young scholars, steeped in distributed lags and the methods of Pontryagin and the Cowles Commissions, was not to a particular macroeconomic model but to following where technicalities and data impelled. They accepted Lucas's interpretation of the Phillips curve, and started working with the new equilibrium concept of rational expectations.

We drink the same water

Robert Hall's invention of a struggle between 'fresh water' and 'salt water' schools of macroeconomics is good theater, but it misleads as a description either of the intellectual origins of equilibrium macroeconomics or of what macroeconomists actually do today. Most of us have been working with a common equilibrium concept, common econometric objects, and common criteria of quantitative success. These common standards – not the particular monetarist environment that he analyzed – are the principal legacy of Lucas's JET paper. These standards have fostered strands of macroeconomic research embodying various assumptions about market completeness and mechanisms of exchange, and diverse approaches to blending theory and evidence.

Legacy

The legacy of the JET paper includes these components: its *style*; its promotion of a *technique*; the substance of its *monetarism*; its use of a *price system* as an imperfect aggregator of information; and its *diffusion*.

Style

Objects of Analysis

The *style* of the JET paper now dominates macroeconomics. Nowadays, most papers start with descriptions of preferences, technologies, endowments, and information, and either work with an equilibrium or are explicit about the pieces of an equilibrium (e.g., an Euler equation) that the paper is about.

Rational Expectations

It is remarkable how rational expectations swept macroeconomics, and how thoroughly 'adaptive expectations' – which was dominant at the time the JET paper appeared – was routed. The victory of rational expectations owes to its beauty and its utility: the economy with which it eliminates what we had thought were free variables – peoples' expectations about endogenous variables – while adding *no* free parameters, but bringing instead cross-equation and cross-frequency restrictions. Adaptive expectations was driven from the field because because it 'overfit' historical data with expectational parameters that profit-seeking would cause to shift with any changes in the stochastic process governing macroeconomic policy instruments. For analyzing such altered government rules, adaptive expectations attributed 'no-response' to the private sector. The *a priori* insistence on best responses, inherited from the types of cross-regime policy question we prefer to study, is what pushed adaptive expectations to the sidelines in macroeconomics, not any consistent pattern of successes turned in by the multitudes of likelihood ratio and Chi-square tests that have been performed on the orthogonality conditions imposed by our models *cum* rational expectations.

Macroeconomics was 'home' to the development of adaptive expectations, in the work of Cagan (1956) and Friedman (1957). Partly via a change of the space in terms of which beliefs are formulated,[8] out of a desire to interpret observations from experimental economics, and out of distress at the presence of large numbers of equilibria, adaptive expectations[9] has made a comeback in other areas of theory, in the guise of non-Bayesian theories of learning. But in macroeconomics, once but no longer a fertile field for loosely connected but plausible packages of ideas, the power of rational expectations as a device for eliminating free parameters has virtually innoculated us against the recurrence of adaptive expectations. This puts us at odds with some good microeconomic theorists these days,[10] which should make either them or us uncomfortable.

Technique

The recursive methods used by Lucas's JET paper, and also by Lucas and Prescott (1971) and Brock and Mirman (1972), have come to dominate macroeconomics. Virtually every macroeconomist today reads, writes, and thinks in terms of dynamic programming. Recursive reasoning unearthed the 'time-consistency' problem, and led to characterizing the types of government policies that could be implemented sequentially.

Substance

[8] As regression *functions* rather than as variables.

[9] Last seen in macroeconomics classes when George Foreman was heavyweight champion of the world the *first* time.

[10] For example, Fudenberg and Kreps.

Time and evidence have weathered the substance of the JET model. The data have mistreated the particular avenue by which monetary shocks work in the JET model, and many early friends of the overlapping generations model of money deserted it in favor of more superficial but more workable alternatives.

Neutrality

Lucas's JET model and its econometric companion (AER, 1973) (an early linear rational expectations model) funneled all real effects of monetary shocks through surprises in the price level. This led researchers to bring Lucas's cross-country attempt at validation home to post-War U.S. business cycles. Early studies found that monetary shocks pushed through this channel could account at best for a minor fraction of the variance of output in post-War U.S. cycles. This failure led to a second round of attempts to find a *direct* empirical role for monetary shocks, unintermediated by the Lucas supply curve. Barro and Mishkin attained results that eventually gave courage to the progenitors of real business cycle theory to neglect *all* monetary and price level disturbances.

Policy Ineffectiveness

Time has broken the 1970's perception, fueled by careless readings of Lucas's JET paper, of a close connection between 'rational expectations' and 'neutrality' or 'policy ineffectiveness.' Nowadays papers in equilibrium macroeconomics are full of numbers purporting to measure the likely output and welfare effects associated with different monetary and fiscal policy arrangements. However, two features of the 1970's research on expectations and neutrality endure: (1) the sharp distinction between the effects of anticipated and unanticipated monetary disturbances; and (2) thinking about government policies in terms of alternative rules mapping states into outcomes.

Belief in 'policy ineffectiveness' survives also in widespread suspicions about the feasibility and/or the desirability of exploiting a 'Phillips curve' tradeoff. Contemporary skepticism about that tradeoff probably owes much to the theoretical writings of Lucas, Phelps, and Friedman, and to some of the evidence presented to support them. Belief in an advantageous Phillips curve, as much as a taste for seigniorage revenues, accounted for many countries' experiments with high inflation regimes during the post World War II years. The intellectual retreat of the Phillips curve helps account for the resurgence of low inflation monetary regimes throughout the world today.

Monetarism

The links to monetarism in Lucas's JET paper were incidental to the methodology of the rational expectations program, but integral to the substance of Lucas's own research program. The *vision* in the JET paper, was not new: it had been passed down by Irving Fisher[11] and Milton Friedman.[12] Like Fisher and Friedman, Lucas's program was guided by the idea that monetary theory should be integrated with price theory in ways that (a) normally preserved as much as possible of the non-monetary theory of relative prices embodied in general equilibrium theory; (b) used the 'quantity theory of money' to determine the price level; and (c) assigned a principal role to monetary disturbances in generating fluctuations, via informational confusion.

The JET framework was not the best vehicle for carrying forward Lucas's vision. It was a zero nominal interest rate economy in which money and government bonds and other assets are potentially perfect substitutes. This feature simultaneously renders it incapable of explaining John R. Hicks's fundamental problem of monetary economics (currency's domination in rate of return by assets of equivalent risk), and vulnerable to Modigliani-Miller theorems for government finance. The tenuousness of fiat money equilibria in the model[13] also makes it a poor vehicle for pricing assets with rates of return exceeding an economy's growth rate. These *desiderata* made the 1972 JET paper the first and last paper Lucas would write in this line. His move to a more superficial and workable approach using cash-in-advance restrictions to generate a demand for base money in the face of rate-of-return dominance at times has disconcerted some of us who had been early converts to what we had heard as a call for an unrelentingly 'deep' approach to modeling monetary and macroeconomic phenomena in terms of explicitly spelled out environments. Lucas's subsequent use of cash-in-advance models showed that his interest in 'depth' was secondary to his respect for a traditional monetary theory embodying a quantity theory of money and a monetary theory of the exchange rate.

Private Information

The JET paper modeled a price system as a function that imperfectly aggregated households' diverse information sets. That idea has been pursued more in financial economics than in macroeconomics, at least recently. The idea was studied in macroeconomics during the decade after JET 1972, but activity dropped off rapidly after that with the 1983 publication of Townsend's 'Forecasting the Forecasts of Others,' which produced a sophisticated model in the tradition of Lucas's JET setup, and Kydland and Prescott's 1982 Time to Build Model, which dropped the 'signal extraction' story that had been a piece of an earlier version of their paper, and pursued the implications of a one shock model without information contaminations. The information aggregation tradition of the JET paper lives on in the literature on 'noise trading.'

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[11] See especially the *Purchasing Power of Money* and 'The Business Cycle: a Dance of the Dollar." Irving Fisher's theory of inflation and nominal interest rates was central to Friedman's 1968 presidential address, but was left out of Lucas's JET paper.

[12] See his presidential address (1968).

[13] See Wallace (1980).

Diffusion

A paper's readers matter nearly as much as its writer. Minnesotans, from the University and the Federal Reserve Bank, were among the first readers of Lucas's JET paper. At Minnesota, the JET paper and other works by Brock, Lucas, and Prescott fueled an intense and respectful dialogue between Christopher Sims and Neil Wallace, often intermediated by their students. Somehow, Sims and Wallace created an atmosphere that attracted several generations of researchers and teachers who have applied and extended the methods of which Lucas's JET paper was a first example.[14]

Ironies

The monetarism of Lucas's JET paper did much to cause rational expectations' rude welcome into macroeconomics, to the accompaniment of dismissive charges that it was 'monetarism mark 2.' Within the scientific community today, equilibrium models overwhelmingly emphasize the primacy of *fiscal* arrangements, even as causes of inflation; while people who like to be called 'new Keynesian' macroeconomists are united principally by their adherence to the *outcomes* of Friedman's 1968 AEA Presidential Address, and occasionally by their resistance to the econometric lessons of the Cowles Commission.

In the early 70's, I thought that Modigliani, Solow, and Tobin – our heroes in those days – were missing the boat by resisting the intrusion of rational expectations into macroeconomics, instead of commandeering it. Despite the appearances of its early incarnations like Lucas's 72 JET paper, the canons of rational expectations models – individual maximization within a consistently understood environment – were evidently wide enough to include Lucas's elegant brand of monetarism or, just as readily, accommodate the completion of Tobin's criticisms of monetarism by fully bringing to bear the logic of Modigliani and Miller. Modigliani, Solow, and Tobin chose not to commandeer the movement, and left it for Kareken, Wallace, Chamley, Bryant and others to draw out many of the non-monetarist implications then waiting to be exposed. The influence of this line of work reflects itself in the fiscalism that today pervades equilibrium macroeconomics.

After 25 years, we are fortunate to meet in Minneapolis to honor the author of 'expectations and the neutrality of money', and to celebrate the type of macroeconomics that reading it helped make possible.

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