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Robert E. Lucas Jr.'s *Collected Papers on Monetary Theory*†

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This paper is a critical review of and a reader's guide to a collection of papers by Robert E. Lucas, Jr. about fruitful ways of using general equilibrium theories to understand measured economic aggregates. These beautifully written and wisely argued papers integrated macroeconomics, microeconomics, finance, and econometrics in ways that restructured big parts of macroeconomic research. (*JEL* A31, E00, E13, E50)

1. *Arrow's Challenge and Lucas's Vision*

Kenneth Arrow (1967, pp. 734–35) identified the relation between microeconomics and macroeconomics as "one of the major scandals of price theory." He doubted that the problem had been resolved "by what Samuelson has called 'the neoclassical synthesis,' in which it is held that achievement of full employment requires Keynesian intervention but that neoclassical theory is valid when full employment is reached." Arrow asserted that "the mutual adjustment of prices and quantities represented by the neoclassical model is an important aspect of reality worthy of the serious analysis that has been bestowed on it" but that to understand depressions and economic development "something beyond, but including, neoclassical theory is needed."

Lucas describes Samuelson's neoclassical synthesis as the core of a Keynesian economics that is remembered now only as a failed research program:[1]

> But what do we mean by "managing" an economy? Prior to Keynes, "managing" was taken to involve a good deal of governmental intervention at the individual market level—socialism in Russia, fascism in Italy and Germany, the confusion of early New Deal programs in the United States. It meant a fundamental shift away from market allocation and towards centralized direction. The central message of Keynes was that there existed a middle ground between these extremes of socialism and laissez faire capitalism. (Actually, there is some confusion as to what Keynes really said—largely

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[1] Chapter 21, section titled "The Death of Keynesian Economics."

> Keynes's own fault. Did you ever actually try to read the *General Theory*? I am giving you Keynes as interpreted by Alvin Hansen and Paul Samuelson.) It is true (Keynes argued) that an economy cannot be left to its own devices, but *all* we need to do to manage it is to manipulate the general level of fiscal and monetary policy. If this is done right, all that elegant nineteenth century economics will be valid and individual markets can be left to take care of themselves. . . . These were hard times, and this was too good a deal to pass up. We took it. So did society as a whole. (Conservatives were a little grumpy, but how bad off could we be in a country where Paul Samuelson is viewed as a leftist?)

> This middle ground is dead. Not because people don't *like* the middle ground any more but because its intellectual rationale has eroded to the point where it is no longer serviceable. . . . the problem in a nutshell was that the Keynes–Samuelson view involved *two* distinct, mutually inconsistent theoretical explanations of the determinants of employment.[2]

Nevertheless, in all but name, a neoclassical synthesis runs through many of the articles in this collection. Competitive equilibria with complete markets abound. Pareto optimal allocations are there, either directly as outcomes or indirectly as benchmarks or ideal points for policymakers, or sometimes just as helpful computational devices.[3] Lucas interprets short- and long-term evidence about the consequences of changes in monetary aggregates by adding credit-market-inhibiting frictions to a modern general equilibrium with centralized multilateral trades in time- and history-contingent commodities. The frictions give people inside the model reasons to hold cash for some transactions despite the presence of extensive credit markets and clearing facilities for making other transactions.

The "Occasional Pieces" in chapter 21 describe ideas and observations that shaped Lucas's research program in monetary economics. In *My Keynesian Education*, Lucas writes "Patinkin and I are both Walrasians, whatever that means. . . . Patinkin's problem was that he was a student of Lange's, and Lange's version of the Walrasian model was already archaic by the end of the 1950s.[4] Arrow and Debreu and McKenzie had redone the whole theory in a clearer, more rigorous, and more flexible way." Lucas shared Patinkin's goal—to achieve an "Integration of Monetary and Value Theory." Lucas wanted to do this in a way that (1) respects "long-run" evidence that substantiates the quantity theory of money, and (2) implies "the smoothing of the money supply (and disregard of interest rate movements) that Friedman and Schwartz argue would have avoided past disasters." He writes, "My contributions to monetary theory have been in incorporating the quantity theory of money into modern, explicitly dynamic modeling . . . ." "When Don Patinkin gave his *Money, Interest, and Prices* the subtitle 'An Integration of Monetary and Value Theory,' value theory meant, to him, a purely static theory of general equilibrium. Fluctuations in production and employment, due to monetary disturbances or to shocks of any other kind, were viewed as inducing disequilibrium adjustments, unrelated to anyone's

[2] See the closely related argument in the second paragraph of Arrow (1967 p. 734).

[3] Even the Ramsey problems of chapters 7 and 9 end up being reformulated as ordinary Pareto problems with pseudo one-period utility functions constructed to include a Lagrange multiplier times a time t contribution to an implementability constraint.

[4] Lange's use of the welfare theorems to provide an intellectual justification for socialism provoked strong reactions. Hayek dissented by saying that the unrealistic assumptions about information embedded in the general equilibrium analysis neglected the important information-processing tasks and incentive problems that a competitive economy handles well and that a command economy does not. That led him to doubt mathematical economics. Another student of Lange's, Leonid Hurwicz, accepted that challenge to mathematical economics by formulating incentive and information problems mathematically.

purposeful behavior, modeled with vast numbers of free parameters. For us, today, value theory refers to models of dynamic economies subject to unpredictable shocks, populated by agents who are good at processing information and making choices over time. [Such] macroeconomic research . . . makes essential use of value theory in this modern sense: formulating explicit models, computing solutions, comparing their behavior quantitatively to observed time series and other data sets."[5]

1.1 *A Phillips Curve that is Not Exploitable*

Chapter 1, "Expectations and the Neutrality of Money," is a paper of remarkable beauty and far flung influence. The paper studies monetary nonneutrality, an issue that involves a "tension between two incompatible ideas—that changes in money are neutral units changes and that they induce movements in employment and production in the same direction—[that] has been at the center of monetary theory at least since Hume wrote. . . . the fact is this is just too difficult a problem for an economist equipped with only verbal methods, even someone of Hume's remarkable powers. . . . The theoretical equipment we have for sharpening and addressing such questions has been vastly improved since Hume's day. . . ."[6] Lucas imagines an economy with overlapping generations of two-period lived agents who are located in informationally separated markets. This is a setting having competitive equilibria in which an unbacked government-issued money has value because it facilitates trades that could not be made otherwise. Demands for money depend on people's expectations about future rates of inflation, which in turn depend on a government's monetary-fiscal policy. *Without* information disparities, there are many ways that the government can distribute newly printed cash, most of which would *not* be neutral, for example, to pay for government purchases of public goods or to finance lump-sum transfers to young people or lump-sum transfers to old people. Each of these expenditure or transfer schemes has nontrivial effects on interest rates, the price level, and allocations.[7] None is neutral. But *without* information discrepancies, there is one way of injecting new cash that *is* neutral: make transfers to all initial holders of currency in proportion to their initial holdings. This special transfer scheme amounts to a change of currency units and is specially designed to eliminate distribution effects, at least within a model of overlapping generations of two-period lived people. Pure units changes should leave all real magnitudes unaltered and simply rescale all nominal magnitudes: multiplying the currency supply by $\lambda > 0$ in this way should simply multiply the price level at all dates by λ.

To obstruct monetary neutrality, Lucas puts such pure units change into an economy in which people inhabit diverse locations. Young people work and save. Old people dissave. There is a joint stochastic process of shocks to people's locations and to cash holding proportional to each old person's initial holdings. The two shocks impinge on price levels at each location in ways that present young people with the statistical problem of disentangling the random transfers to old people from the real shocks reallocating people across locations (Phelps's "islands"). Because young people disentangle the shocks imperfectly, those pure units changes affect relative prices and young people's labor supply decisions. This creates a Phillips curve—random fluctuations in money transfers that

[5] Chapter 19, "Macroeconomic Priorities."
[6] Chapter 16, "Nobel Lecture: Monetary Neutrality."
[7] "We need to be explicit (another point in favor of Samuelson's [overlapping generations] model) about the way the new money gets into the system, and it matters how it is done." (Chapter 16, "Nobel Lecture: Monetary Neutrality")

cause employment to fluctuate. The Phillips curve is not exploitable: only unanticipated components of money transfers provoke fluctuations in employment and, under rational expectations, the government cannot systematically induce forecast errors. So far as employment is concerned, all perfectly predictable money supply growth rate rules—say any of Milton Friedman's k percent money growth rules—lead to the same real allocation, but different price-level paths. So the model leads to a sharp difference in the effects of unanticipated and anticipated changes in the money supply, at least ones accomplished by pure transfers that are proportional to people's initial holdings of money. Also, according to a particular welfare criterion Lucas uses, any k percent rule leads to a Pareto optimal allocation and is as good as any other k percent rule.

In chapter 16 "Nobel Lecture: Monetary Neutrality," Lucas returns to his chapter 1 model and an early eighteenth century example of a "pure units change" experiment described by David Hume and someone named Dutot—an experiment studied further by Velde (2009). In the 1720s, French silver and gold coins did not have numbers on them, only images and words. The government regulated the number of units of account each coin signified, with units of account being approximately proportional to the rare metal contents of coins of different denominations. Because it wanted to revalue claims against the government owned by government creditors, the French government suddenly declared surprise changes in the units of account attached to the entire denomination structure of coins, just as in Hume's or Lucas's experiment. Velde assembles quantity and price data at dates surrounding those unanticipated units changes. He finds what look like immediate neutrality for foreign exchange rates, but transient real effects and gradual price level responses lasting around two years in goods markets. Velde doubts that a disparate information story like Lucas's would work for these episodes, both because the government widely broadcast the units change and because the markets for those Phillips-curves exhibiting commodities were in very close physical proximity to the market for foreign exchange.

"Expectations and the Neutrality of Money" had an immense impact on many of us. It made us appreciate the power of applied welfare economics and that we should reconstruct macroeconomics with the tools of mathematical economics. It abruptly forced us to learn about contraction mappings and the notion of a rational expectations equilibrium as a fixed point in a space of functions. It compelled us to rethink the connections among theory, econometrics, and data. It introduced a distinction between anticipated and unanticipated policies that was the core of 1970s so-called "policy ineffectiveness" results that set the stage for reexaminations of the starts and ends of big inflations. It made clear the close connection between monetary and fiscal policies, not as one-time sets of actions, but as functions mapping states into government actions. It inspired a sequence of contributions by Neil Wallace and his coauthors that used the two-period overlapping generations model to analyze old and new questions about monetary and fiscal policy. It put rational expectations to work in a general equilibrium context for one of the first times, applying Muth's idea of a rational expectations equilibrium not to a simple textbook cobweb cycle example but instead to one of the most pressing macro issues of the day, what James Tobin had called the "cruel choice" between inflation and unemployment. Lucas showed that there was no cruel choice.

It is interesting that Lucas used the overlapping generations structure with two-period lived agents only for this one magnificent paper. By the late 1970s, he had switched to a setting with an infinitely lived

representative family having a more direct connection to a competitive equilibrium of a standard Arrow–Debreu model (one satisfying the welfare theorems without fiat money), while adopting a more direct way of introducing valued fiat currency through cash-in-advance constraints. My guess is that the reason for this change in Lucas's preferred setup was that he wanted to manage distribution effects. The infinite horizon representative family model is rigged to quarantine distribution effects, while they are paramount in the overlapping generations model. Another reason was the infinite horizon representative agent model's susceptibility to analysis through dynamic programming and recursive competitive equilibria.

1.2 *Lucas's Ultimate Way of Doing Monetary Theory*

In a number of key papers in this collection, to "incorporat[e] the quantity theory of money into modern, explicitly dynamic modeling," Lucas started with a modern general equilibrium model, then added financial frictions that disturb equilibrium allocations and prices. He did this in ways designed to capture big transient effects of unanticipated money supply changes on allocations. The art was to do this in ways that render tractable an analysis in terms of aggregate quantities. James Tobin said that macroeconomics is a subject that attains workable approximations by ignoring effects on aggregates of distributions of wealth and income.[8] This characterization of macroeconomics carries with it a tension with monetary theory because trades made with cash are bilateral and cannot be or are not accomplished by exchanging credits. The presence of cash transactions requires tracking cross-section distributions of money and the composition of traders' portfolios—a summary measure of wealth is not enough. A major source of Arrow's "scandal" was that in the Arrow–Debreu model of general equilibrium, all trades are multilateral; they are accomplished through a credit system that comprehensively nets out claims. There is no role for cash because there are no bilateral transactions. In several of the core papers in this volume, Lucas alters a standard Arrow–Debreu model to require people only temporarily to engage in bilateral transactions using cash, while still allowing them regularly to participate in centralized securities markets. "The construction of a multiple-member household that pools its resources at the end of each day is the device that permits us to study situations in which different individuals have different trading opportunities during a period, while retaining the simplicity of the representative household."[9] Lucas introduces timing protocols and frictions that make room for a quantity theory of money while still preserving much of the structure of a nonmonetary economy (i.e., one having the same preferences, endowments, and technologies, but without the frictions that force people sometimes to use money). Optimal allocations are still there, now as normative benchmarks that monetary and fiscal policies should strive to approximate.

Lucas said "There is little doubt that the main task of monetary economics now is to catch up with our colleagues in finance, though the question of how this may best be done must be regarded as considerably more open."[10] In "Money and a Theory of Finance," chapter 8 of this collection, Lucas summarizes his research program that uses

[8] In Chapter 6, "Interest Rates and Currency Prices in a Two-Country World," Lucas relies heavily on the following insight: "Agents are risk averse, so they will be interested in pooling these endowment risks, and since they have identical preferences, an equilibrium in which all agents hold the same portfolio will, if ever attained, be indefinitely maintained." By assuming identical initial portfolios, Lucas permanently shuts down distribution effects on aggregates.

[9] From Chapter 13, "Liquidity and Interest Rates."

[10] Chapter 6, "Interest Rates and Currency Prices in a Two-Country World."

the Arrow–Debreu general equilibrium model as a linchpin for integrating theories of finance and money:

> If it is easier today than in 1960 to identify exactly in which respects the theory of finance fails as a monetary theory, this is largely due to rapid progress in the theory of finance. Theoretical research in finance is now conducted almost entirely within the contingent-claim framework introduced by Arrow (1964) and Debreu (1959). This is not an historical statement, for each of the three pillars of modern financial theory—portfolio theory, the Modigliani–Miller Theorem, and the theory of efficient markets—was discovered within different (and mutually distinct) theoretical frameworks, but all three have since been reformulated in contingent-claims terms, and it was this reformulation that revealed their essential unity and set the stage for many further theoretical advances. . . .
>
> A central feature of this model is that *all* trading occurs in a centralized market, with all agents present. In such a setting, the position of each agent is fully described by a single number: his wealth, or the market value of all the claims he owns. The command any one claim has over goods is fully described by its market value, which is to say all claims are equally "liquid". If the point of a theory of money, or of "liquidity preference," is to capture the fact that, in some situations in reality, money has a relative command over other goods *in excess of* its relative value in centralized securities trading, then a successful theoretical model must place agents in such situations, at least some of the time. . . . the monetary model introduced [here] employs a device . . . in which agents alternate between two different kinds of market situations. Each period, they all attend a securities market in which money and all other securities are exchanged. Subsequent to securities trading, agents trade in (implicitly) decentralized goods markets in which the purchase of at least some goods is assumed subject to the cash-in-advance constraint . . . The assumption of this model that agents regularly, if not continuously, trade in a centralized securities market admits a theory of securities pricing that is close to the standard barter theory . . . the idea that success in [the enterprise of unifying theories of money and finance] will involve capturing in a single model the sense in which securities are traded and priced in centralized "efficient" markets as well as the sense in which other goods are traded outside of these centralized exchanges, in situations where at least one security ("money") is valued higher than it "ought" to be on efficient markets grounds alone . . . is present in most writing on money.

But Lucas points to empirical findings that threaten tightly connected theories of finance and macroeconomics.

> Ultimately, however, financial and monetary theory have quite different objectives, and however desirable theoretical "unity" may be, one can identify strong forces that will continue to pull apart these two bodies of theory. . . . The empirical failures of the simplest "representative consumer" models indicate that increased generality is required to produce success in the sense of first-order conditions that can pass the modern descendants of the efficiency test of finance. Such generality is not difficult to obtain, and I expect much additional fruitful work in this direction.[11] The objective of designing simulatable models, an objective central to monetary theory, necessarily pulls in the opposite direction. . . . If I am right that the relationship between financial and monetary economics is not, even ideally, one of "unity", it is nevertheless surely the case that there is much to be gained by close interaction. The power in applications of the contingent-claim point of view, so clearly evident in finance, will be as usefully applied to monetary theory.

Never far off stage are two good friends who have persistently challenged Lucas's tastes and decisions about how to do research in monetary theory: Edward C. Prescott and Neil Wallace.

[11] Hansen and Singleton (1983) document empirical shortcomings of Euler equations based on versions of the asset pricing model described by Lucas in chapter 2 of this collection. Hansen, Heaton, and Li (2008) illustrate ways of specifying the preferences of the representative agent and the exogenous stochastic process for per capita consumption in ways to improve the theory's harmony with the data.

Prescott ignores or dismisses Friedman and Schwartz's evidence that Lucas cares so much about, regards monetary policy as a side show, and recommends that the best way to study business cycles and growth is to stick with an entirely real Arrow–Debreu model. Thus, Prescott's way of confronting Arrow's "scandal" about the need to reconcile macroeconomics with general equilibrium theory is to declare that a very special case of an Arrow–Debreu general equilibrium model does an excellent job of explaining business cycles.

Although for some purposes Lucas admires Kydland and Prescott's real business cycle model, he warns that it is of limited use:

> Since Kydland and Prescott's surprising (1982) demonstration that productivity shocks with realistic statistical properties can account for *all* real output variability in the post–World War II U.S. economy, the need for a theory of monetary sources of instability has come to seem much less pressing. This important finding has been buttressed by much subsequent research, but it is an "R^2" finding that does not bear directly on the size of the money multiplier. Nothing in the recent volume of real business cycle research shows, or even suggests, that a sudden monetary contraction would have negligible output and employment effects, and that monetary policy is therefore of little real importance.[12]

> One may thus think of the [Kydland–Prescott real business cycle] model not as a positive theory suited to all historical time periods but as a normative benchmark providing a good approximation to events when monetary policy is conducted well and a bad approximation when it is not. Viewed in this way, the theory's relative success in accounting for postwar experience can be interpreted as evidence that postwar monetary policy has resulted in near-efficient behavior, not as evidence that money doesn't matter. Indeed, the discipline of real business cycle theory has made it more difficult to defend real alternatives to a monetary account of the 1930s than it was 30 years ago. It would be a term-paper size exercise, for example, to work out the possible effects of the 1930 Smoot–Hawley Tariff in a suitably adapted real business cycle model. By now, we have accumulated enough quantitative experience with such models to be sure that the aggregate effects of such a policy (in an economy with a 5 percent foreign trade sector before the Act and perhaps a percentage point less after) would be trivial.[13]

Unlike Prescott, Wallace thinks monetary economics is important and that we should be patient enough to construct a monetary theory from first principles. He sees bilateral trades as pervasive and regards the multilateral trades assumed in the Arrow–Debreu structure as fatal to its utility as a starting point for a useful monetary theory. Wallace sees Lucas's favorite way of amending an Arrow–Debreu model by adding financial frictions that take "cash" as a primitive object as begging some of the most important questions that a good theory of money should answer, such as what objects are and are not used to effect bilateral and multilateral exchanges. Cash-in-advance models blatantly violate axioms that Wallace requires of a good monetary theory.[14]

Lucas responded in ways that reveal that he was not especially disturbed by Neil Wallace's opinion that his monetary theory is too superficial. According to Lucas, "Applied theory is always a mixture of rigor and compromise."[15] "Ultimately, the merits of a particular approach to the theory of money (as to the theory of anything else) will be judged less by its axioms than by whether it seems capable of giving reliable answers to the substantive questions that lead us to be interested in monetary theory in the first place."[16] "Successful applied science is done at many

[12] From chapter 12.

[13] From chapter 21, section with review of Friedman and Schwartz.

[14] For example, see Wallace (1998).

[15] Chapter 1, "Introduction by Robert E. Lucas Jr."

[16] From Chapter 8, "Money in a Theory of Finance."

levels, sometimes close to its foundations, sometimes far away from them or without them altogether. . . . The analysis of sustained inflation illustrates this observation, I think: Though monetary theory notoriously lacks a generally accepted 'microeconomic foundation,' the quantity theory of money has attained considerable empirical success as a positive theory of inflation."[17] Examples of Lucas purposefully taking as given things that a deeper analysis would take as outcomes of explicitly modeled choices occur throughout the book.[18]

1.3 *Frictions and Government Policies*

Lucas's cash-in-advance models are leading examples of a much broader class of modern models with financial frictions that typically have the following structure. A model builder adds financial frictions—cash-in-advance constraints or collateral constraints or ad hoc borrowing constraints—to an otherwise well-functioning general equilibrium model. Some people inside the model are subject to these constraints (the private agents), while others are not (government fiscal and/or monetary authorities). As part of an optimal plan, a Ramsey planner tells the government to relax the financial restrictions. In Lucas's models, this materializes in recommendations to implement a Friedman rule or free banking. A government monopoly on issuing cash coupled with an effective cash-in-advance constraint opens what Friedman (1960) called "inefficiencies and incentives for avoidance." These difficulties shape optimal monetary-fiscal policy problems in cash-in-advance models. To purchase goods during periodic "shopping periods," the model builder forces households to hold cash that bears zero nominal interest and that can be issued only by the government. When the cash-in-advance constraint binds, the nominal interest rate on safe evidences of indebtedness is positive, signaling the presence of both the inefficiencies mentioned by Friedman and of an "incentive for avoidance" in the form of an arbitrage opportunity (borrow at zero nominal interest by issuing cash and lend it at the prevailing positive nominal rate). Only the government can exploit this arbitrage opportunity. If there were free entry of private intermediaries into the business of issuing cash, equilibrium nominal interest rates would be zero and no good purpose would be served by government intervention.[19]

What features of the economic environment account for the cash-in-advance constraint? (Wallace lurks in the shadows here.) Lucas says that legal regulations on intermediation can or maybe should give rise to cash-in-advance constraints. "The question 'What is Money?' becomes, then, the question of what we want to *make into* money via government restrictions of various kinds on the operation of the private banking system." He calls for analyzing the merits of such restrictions partly by comparing the "poor business cycle experience of those economies with relatively unregulated banking with . . . [economies] (such as ours) in which institutions

[17] From Chapter 17, "Inflation and Welfare."

[18] The model of Lagos and Wright (2005), constructed along lines professing to respect Wallace's dicta more than does the Lucas–Stokey cash-in-advance model of chapter 10, nevertheless shares many features of the chapter 10 model, mainly because Lagos and Wright designed it to have many of the convenient operating characteristics of Lucas and Stokey's model.

[19] Complete deregulation that permits free entry into the business of supplying cash supports an optimal allocation. However, with free banking, valued fiat money disappears in the limit, rendering the model useless for confronting the quantity theory observations that interest Lucas. Wallace (1998) would take this outcome as an indication that fiat money is "not essential" in the economic environment of Lucas's cash-in-advance model. Friedman (1960, p. 4) conceded that the choice between the free banking regime recommended by Becker (1956) versus his preferred narrow banking regime with 100 percent reserves together with paying interest on reserves at a market rate is a close call.

providing transactions-effective services are sharply differentiated by legal restrictions [under the Glass Steagall Act] that necessarily oppose the competitive forces working to blur these restrictions." (This was written long before U.S. financial deregulation in the 1990s.) He also writes that "The question we face now is not whether there is some 'natural' reason to treat *M*1 as an interesting number but whether we want to enforce an 'unnatural' situation that will make it interesting."

1.4 *Flexible and Sticky Prices*

Chapter 6, "Interest Rates and Currency Prices in a Two Country World," analyzes asset pricing and exchange rates in a two-country model with flexible prices. Lucas sets things up carefully to suppress effects of shocks on the distribution of wealth, so that ". . . securities pricing [can] be studied under the provisional hypothesis that agents of both countries hold identical portfolios." It is instructive to watch Lucas assemble the assumptions that make this work. Alternative cash-in-advance constraints give rise to one-currency and two-currency versions of the model that allow analyzing differences between fixed and flexible exchange rate regimes and for establishing their equivalence in terms of allocations and all relative prices: ". . . a second money was introduced and trade in the two currencies was permitted. Again, with stable money supplies, relative prices and quantities are not altered. This redundant security [the second money] does no harm. It also does no good, however, and thus when it is effectively removed, . . . the efficiency properties of the real resource allocation are left undisturbed. . . . One frequently sees exchange rate regimes compared in terms of where it is that certain shocks get 'absorbed'. In the present model, with perfectly flexible prices in all markets, 'shock absorption' is easy and the issue of which prices respond to which shocks is of no welfare consequence."

Lucas emphasizes the role of assumptions he makes about the initial distribution of wealth across people in the two countries:

> The fact that, in equilibrium, all traders in the world hold the identical market portfolio is a simplification that is absolutely crucial to the mode of analysis used above. It is also grossly at variance with what we know about the spatial distribution of portfolios; . . . Why is this? . . . A real answer must have something to do with the local nature of the information people have, but it is difficult to think of models that even make a beginning on understanding this issue. It is encouraging that the theory of finance has obtained theories of securities price behavior that do very well empirically based on this common portfolio assumption, even though their predictions on portfolio composition are as badly off as those of this paper.

The irrelevance results in the chapter 6 model hinge sensitively on the flexibility of competitive equilibrium prices.[20] The assumption of flexible prices also plays a big role in chapters 6, 8, 9, 10, and 13, while chapters 1 and 16 are about how information disparities can make what seem to be sticky prices emerge from an economy with completely flexible prices. In contrast, chapters 12, "The Effects of Monetary Shocks When Prices are Set in Advance," and 20 (written with Mikhail Golosov) assume that prices are sticky, and that individual agents set them, not an Arrow–Debreu invisible hand. These chapters are efforts to make progress on an issue that Lucas describes in this way in chapter 15: "I do not see how [the question of the appropriate conduct of monetary policy] can be resolved without better theories of price rigidity than we now have available to us." In chapter 12, Lucas warns us that

[20] For other irrelevance theorems, see Wallace (1981). Some of these don't seem to require flexible prices, just care in constructing policies that keep all agents' budget constraints satisfied at an initial equilibrium price vector.

this is going to be a grim and difficult task yielding outcomes of qualified applicability:

> . . . is a money multiplier a structural parameter? No, of course it isn't. One purpose of models such as those in [chapter 12] is to understand the ways in which changes in policy parameters affect this multiplier, but even to do this one needs to take as fixed other parameters—the length of the period over which prices are fixed, say, or the length of information lags or labor contracts—which must in fact react to sufficiently large changes in policy. . . . a money multiplier is *never* going to be recognized by the American Kennel Club. I think if we are to use economic theory to improve monetary policy and institutions, we are just going to have to get used to this.

We are still getting used to it, as recent papers extending the chapter 20 Golosov–Lucas model attest. Lucas lets us know that this kind of work is not for the faint of heart who are likely to be scared off by Wallace's dicta. Of the chapter 12 model, Lucas tells us directly: "In its reliance on nominal prices that are set in advance, . . . I offer no explanation beyond an appeal to descriptive realism for the assumption that prices are pre-set, or for the assumption that they are set in dollars rather tha[n], say eggs or pork bellies or yen." Sticky price models are like Vietnam and Iraq: don't think you can get in and out quickly.

The chapter 20 Golosov–Lucas model extends earlier general equilibrium menu cost models of Caplin and Spulber (1987) and Caplin and Leahy (1991) that feature a distribution of firms' relative prices whose positions within S, s bands are determined by a monetary shock that would be neutral if menu costs were zero. Caplin and Spulber (1987) obtained a neutrality result that stems from a selection effect coming from firms being able to decide when to change prices. The Calvo (1983) model shut down that selection force by not allowing firms to decide *when* to reset their prices, only how much to change them when an exogenous Poisson counter gives them an opportunity. The selection force identified by Caplin and Spulber is present in all general equilibrium menu-cost models and is a persistent obstacle to generating nonneutrality of monetary shocks. Caplin and Leahy (1991) recover monetary nonneutrality despite the selection effect by generating a time-varying cross-section of price changes.

A principal aim of the menu-cost literature is to disrupt monetary neutrality more broadly in ways that are consistent with growing bodies of micro panel evidence about prices. The Golosov–Lucas model uses idiosyncratic productivity shocks to explain frequent micro and large price-level changes that cannot be explained by the aggregate shocks driving outcomes in earlier models. In the observed features of micro price changes that it misses, as well as in the small departures from neutrality it delivers in the end, Golosov and Lucas's paper set the stage for a string of subsequent menu-cost models. Gertler and Leahy (2008) introduced Poisson idiosyncratic shocks as a way to get better accounts of the dispersion and size of price changes. Midrigan (2011) added multiproduct firms and economies of scope in adjusting posted and regular prices to induce more small and temporary price changes. Alvarez and Lippi (2014) refined the study of multiproduct firms with a tractable analytical framework that allowed them to study the consequences of monetary shocks in terms of parameters governing moments of cross section distributions of prices. Vavra (2014) added stochastic volatility to idiosyncratic shocks as a way of explaining what he interprets as time-varying price stickiness.

1.5 *Modeling Money Supply Changes*

In the overlapping generations model of chapter 1, it matters how new unbacked government issued currency is distributed. It also matters that the equilibrium in the

chapter 1 model is one where no asset dominates government-issued currency in rate of return, while in cash-in-advance models, currency is in general dominated in rate of return by interest-bearing claims on the government or the representative consumer. In cash-in-advance models, Lucas does not inject money via transfers proportional to initial holdings as he does in chapter 1. Instead, Lucas studies a peculiar[21] kind of open market operation in which the government purchases interest bearing securities. Such a purchase affects interest earned by private agents and the government. In Lucas's experiment, the government disposes of its altered interest earnings by making a simultaneous lump sum transfer to the representative household, a fiscal component of the experiment needed to get a purely neutral quantity theory outcome.

1.6 *Rational Expectations and Complete Markets*

To create workable rational expectations models, Lucas and Prescott exploited links between an Arrow–Debreu competitive equilibrium and an equivalent economy with sequential trades of securities (e.g., a Lucas tree or some collection of Arrow securities). In an Arrow–Debreu economy with all trades at time 0, no one has to forecast prices; people see the prices at which they trade once and for all at time 0. But in an economy with frequent sequential trades of a much smaller number of securities than those traded in that Arrow–Debreu economy, people do have to forecast prices when they choose things like consumption rates, labor supplies, and portfolios at each date. Optimal forecasting rules associated with a rational expectations equilibrium can be constructed by recognizing the connection between these two economies, a technical device that pervades applied dynamic analysis today and underlies the concept of a recursive competitive equilibrium.

It is enlightening to hear Lucas explain how things work: "In this 'sequence economy' reinterpretation of an Arrow–Debreu economy, one is free, without affecting the analysis of equilibria, to think of prices . . . not as being set at time 0 but rather as being correctly or rationally *expected* (as of $t = 0$) to be set in the time-t market should the history s^t be realized. That is, one thinks of certain prices as being formally established at each date, in light of rational expectations as to how certain other prices will be set later . . . it will be useful . . . to think of these equilibrium conditions as describing the evolution of a competitive system with rational expectations."

1.7 *Rational Expectations and Time Inconsistency*

It is no coincidence that Kydland and Prescott (1977) analyzed time inconsistent plans only after Lucas and Prescott had first brought rational expectations into macroeconomics. Rational expectations are the "behavioral economics" associated with the time inconsistency of optimal government plans. When at some initial time 0, a government once and for all simultaneously chooses its current action and all future actions, the rational expectations hypothesis implies that it is also choosing the public's expectations about those actions. Therefore, these future government actions immediately influence all earlier private actions. The government takes this into account in choosing its comprehensive plan at time 0. This means that when it chooses its time $t > 0$ actions, the government does not take time $s < t$ actions of the private sector as given.

Lucas puts it this way: ". . . a discrepancy between the best future tax policies to announce today and the best policy actually to execute when the future

[21] It is peculiar because it is not purely a portfolio management operation, but requires a tax adjustment too.

arrives is precisely what is meant by time-inconsistency." "[Time-inconsistency of government policy] arises, more generally, whenever the private sector must first commit itself to a current decision on the basis of its beliefs about a future action taken by government, and then, with this commitment made, the government is free to select this future action."

Kydland and Prescott (1977) took the natural timing protocol in most democratic societies to be the sequential one and not the simultaneous once-and-for-all at time 0 timing protocol associated with the optimal plan. From that opinion about timing protocols, they drew the pessimistic inference that optimal plans were unlikely to prevail in practice.

If left unchallenged, the Kydland and Prescott's conclusion snuffs out any practical significance to be attached to the Ramsey plans for optimal monetary and fiscal policy constructed in key papers in this book. As Lucas says, "Since the normative advice to a society to follow a specific 'optimal' policy is operational only if that policy might conceivably be carried out over time under the political institutions within which that society operates, the Kydland–Prescott paper calls into serious question the applicability of all dynamic adaptations of the Ramsey framework."

Subsequent work on credible government plans by Stokey (1989, 1991), Chari and Kehoe (1990), and Bassetto (2005) adapt and extend insights from the theory of repeated games in attempts to restore interest in Ramsey plans. These authors explore a larger set of rational expectations equilibria than those originally considered by Kydland and Prescott. By allowing more history dependence of decisions and private sector expectations than had originally been assumed by Kydland and Prescott, these can potentially induce a government to choose better policies than Kydland and Prescott predicted under the sequential timing protocol.[22] A government plan is a sequence of functions whose time t component maps a history of outcomes before time t into a government action at time t. The theory assigns these functions a dual role: they are decision rules of the time t government, as well as functions that the private sector uses to forecast government actions. Stokey calls a plan credible if it is in the interest of the government at each date and each history to carry out the plan. The plan attaches consequences to confirming the plan and deviating from it that induce a government always to confirm the plan. To make this work, the members of the sequence of functions comprising the plan must be history dependent.

One needs to appeal to *something* in order to restore practical interest to optimal plans calculated at time 0 in the face of the conclusions presented by Kydland and Prescott (1977). Lucas does not formally appeal to the literature on credible plans in this volume,[23] but he does describe systems of beliefs that serve to weaken the temptations to deviate from a time-inconsistent optimal plan that arise under a sequential timing protocol:

> In common with written constitutions, each of these disciplines can be amended or evaded, an observation that has led to some skepticism about the usefulness of trying to bind economic policy at all. What is the "discipline" of a monetary standard if the government always has the option to devalue? This is a difficult question, I think, because it is a poor response to conclude that since the effectiveness of such disciplines is hard to measure, they are unimportant forces. Certainly there are innumerable episodes in U.S. history where disciplines

[22] They can also induce a government to choose *worse* policies. The theory brings *sets* of credible government policies. Stokey (1989, 1991) and Chari and Kehoe (1990) focused on the best credible policies.

[23] The pertinent articles in this volume were written before the research on credible plans in macroeconomics; indeed, aspects of that literature were inspired by some of the papers in this collection.

like these appear to have been, for better or worse, binding constraints on policy.[24]

1.8 *Empirical Evidence about the Quantity Theory of Money*

Lucas (1972) criticized tests of the natural-rate hypothesis that had been proposed by Solow and Tobin, tests that check whether the sum of the coefficients in a projection of unemployment on a long distributed lag of inflation equal zero. Lucas constructed an example in which a rational-expectations version of the natural-rate hypothesis prevails; nevertheless, Solow and Tobin's test rejects the natural rate hypothesis because the low-frequency restriction imposed by Tobin and Solow's "adaptive expectations" scheme is in general false under rational expectations. Lucas proceeded to describe a more appropriate econometric test that embeds the cross-equation restrictions implied by rational expectations. The analysis of the Phillips curve in Lucas's 1972 paper became one of three examples used to illustrate how properly to impose rational expectations econometrically in the famous critique by Lucas (1976).

In light of the 1972 paper on econometric testing, it is perhaps unexpected that in his 1980 paper, "Two Illustrations of the Quantity Theory of Money," in chapter 4, Lucas relies on those discredited Solow–Tobin restrictions to assemble evidence about long-run neutrality of money. He uses a graphical method to display sums of coefficients in ordinary least squares regressions of inflation on a long two-sided distributed lag of money growth, and of an interest rate on a long two-sided distributed lag of money growth.[25] Lucas takes unit values of those coefficients and good fits as evidence in favor of what he says are long-run implications of the quantity theory of money. Lucas does not deduce that unit sum restriction from a particular monetary model taken from one of the chapters of this collection. Instead he argues informally that the restriction can be expected to prevail across a broad *class* of models.[26] "The modifier 'long run' is not free of ambiguity, but by any definition the use of data that are heavily averaged over time should isolate only long-run effects."[27]

It is significant that "Two Illustrations," which summarizes an important part of the evidence that Lucas used to guide his research program of "incorporating the quantity theory of money into modern, explicitly dynamic modeling" ignores the cross-frequency restrictions present in all rational expectations models and instead makes inferences from low-frequency relationships alone. Lucas's data processing choice here must have been inspired by his wish for a procedure that is informative about outcomes that can be expected to prevail across a class of models, many of which have not been specified, and some or all of which are probably misspecified in the sense that they apply a joint distribution for *all* observable outcomes that contradicts aspects of the data. How to acquire evidence about a *class* of models, and how to do plausible quantitative economics in light of a model that you admit is wrong, are themes that run through many of the papers in the book.[28]

[24] Chapter 9, "Principles of Fiscal and Monetary Policy."

[25] Lucas's procedure of plotting symmetric two-sided, low decay rate geometric averages of two series against each other is a way of estimating the sum of coefficients in a two-sided distributed lag.

[26] See King and Watson (1994) for a discussion of special circumstances that render the unit sum restrictions consistent with rational expectations, and Whiteman (1984) for a critical analysis that chides Lucas for not proceeding as he had recommended in Lucas (1976).

[27] Chapter 16, "Nobel Lecture: Monetary Neutrality."

[28] Hansen and Sargent (1993) constructed examples in which imposing *wrong* cross-equation and cross-frequency restrictions by filtering data improves estimates of parameters of interest in a setting where a model builder trusts some features of a model (e.g., its preferences or technologies) more than others (e.g., details of exogenous driving and shock processes). It seems likely that a formal analysis of estimation strategies for misspecified models along these lines would carry further insights about Lucas's empirical strategy in the "Two Illustrations" paper.

Between 1972 and 1980, *something* caused Lucas to retreat from rational expectations econometrics and to seek looser and more forgiving data matching procedures. I think that it was Lucas's reaction to outcomes from early applications of rational expectations econometrics. By turning up one model rejection after another, starting in the mid 1970s, applications of likelihood ratio tests to rational expectations models demonstrated just how powerful those cross-equation restrictions are: powerful enough that they mistreated some models that we liked. It presented challenges that, as Lucas remarked, those tests "brought a degree of empirical stringency without precedent in economic research."[29] Distributed throughout the papers in this collection are discerning comments about how to compare admittedly false models to data and about whether models that have failed some econometric specification tests are still useful.

1.9 *Euler Equations and Computed General Equilibria*

Lucas states and acts on his preference to acquire insights from general equilibrium theories despite negative reflections on key Euler equations that have repeatedly come from rational expectations econometric tests. In the face of discouraging empirical evidence about at least some pieces of a model, Lucas proceeds to gather insights about the balance of forces that prevail in a general equilibrium.

He summarizes a theme that recurs throughout the collection when he writes

> From the point of view of classical hypothesis testing, nothing is gained in restricting attention to models that have solutions or solutions that can be characterized or simulated. If a [particular] first-order condition . . . is tested and rejected, one can view as rejected all models carrying this equality as an implication, without having to spell out each model or verify its internal consistency. Since there is no doubt that with rich enough data sets any such condition will be rejected, a research program based on purely negative application of first-order conditions has, in a sense, inexhaustible possibilities. Yet I think it is clear that pursuit of this line is at best a useful adjunct in the effort to obtain simulateable, necessarily "false" models that have the potential for shedding light on the questions that lead us to be interested in monetary theory in the first place.

A striking part of this passage is Lucas's faith that "false" models can teach. Experienced applied researchers in all sciences understand models as imperfect imitations.[30] But the view that models are approximations raises special issues for rational expectations econometrics and, for that matter, for *all* alternative methods for doing quantitative work with a rational expectations model, like calibration. Rational expectations econometrics relies heavily on a common probability model being shared by nature, the agents inside a model, and the economists and econometricians outside a model. By making artificial agents "inside" a model and economists "outside" a model contemplate multiple probability models, recognizing model misspecification takes us into the domain of recent literatures on robustness and model ambiguity.[31]

1.10 *Ambivalence Toward Twin Papers*

Chapter 2 ("Asset Prices in an Exchange Economy") and chapter 19 ("Macroeconomic Priorities") use essentially the same model,

[29] Rational expectations econometrics presents diagnostics that help to locate dimensions of a model that are most in need of repair.

[30] Gilboa et al. (2011, 2014) discuss how to extract useable lessons from a model whose author regards it as a metaphor.

[31] Specification uncertainty "inside" models is the subject of Hansen and Sargent (2014), while approaching specfication uncertainty both "inside" and "outside" models is the subject of Hansen (2014).

but for different purposes, and in ways that convey Lucas's attitude toward the model. Both chapters feature the same representative consumer whose preferences over alternative exogenous consumption processes are described by a mathematical expectation of discounted utilities. Chapter 2 uses marginal utilities evaluated at an exogenous consumption process to value an asset whose dividends equal consumption (what has come to be called a "Lucas tree"). Chapter 19 calibrates the exogenous consumption process to match outcomes actually obtained under post WWII macroeconomic stabilization policies and then evaluates expected discounted utility under that process. Lucas then calculates how much the representative consumer would be willing to lower the level of the consumption process in exchange for a reduction in its conditional volatility to zero. This calculation turns on the curvature of the utility function as parameterized by the coefficient of relative risk aversion; the same parameter that determines the market price of risk in the same model applied to asset pricing in chapter 2.[32]

Taking the per capita consumption process to be exogenous is a good assumption for both chapters. Why? For the asset pricing model of chapter 2, extending the model to make consumption endogenous would only *add* cross-equation econometric restrictions. For the chapter 19 exercise that evaluates the prospective gains to further macroeconomic stabilization, all that matters for expected utility is the per capita income process that emerged from post WWII stabilization policies. The details about the stabilization policies that produced that outcome don't influence the prospective gains.

Empirical studies of the Lucas asset pricing model indicate that matching observed market prices of risk in light of the low volatility of the log of per capita consumption witnessed in post–World War II U.S. data requires very high coefficients of relative risk aversion.[33] Despite that, for the chapter 19 calculations, Lucas chooses to use a low value of the coefficient of risk aversion. He explains why he turns his back on the asset pricing implications of his chapter 2 model: "The risk-aversion levels needed to match the equity premium, under the assumption that asset markets are complete, ought to show up somewhere besides securities prices, but they do not seem to do so. No one has found risk-aversion parameters of 50 or 100 in the diversification of individual portfolios, in the level of insurance deductibles, in the wage premiums associated with occupations with high earnings risk, or in the revenues raised by state-operated lotteries. It would be good to have the equity premium resolved, but I think we need to look beyond high estimates of risk aversion to do it."[34]

A melodramatic way to read chapter 19 is that we are watching the father of the chapter 2 Lucas asset pricing model abandon his child. Lucas doubts that his chapter 2 model captures the all important "mutual adjustment of prices and quantities represented by the neoclassical model [that] is an important aspect of reality" (Arrow 1967, p.734–35). But stressing the quantity implications of a general equilibrium model while ignoring its implications about prices as he does in chapter 19 is a delicate matter, especially within a research program that emphasizes how prices for Arrow securities shape the allocation of resources. His presentations of this

[32] The market price of risk is defined as the coefficient of variation of the stochastic discount factor $\beta \frac{u'(c_{t+1})}{u'(c_t)}$.

[33] Even then the model has problems, for example, because a high coefficient of relative risk aversion pushes up the risk-free rate too high.

[34] Hansen, Heaton, and Li (2008), Barillas, Hansen, and Sargent (2009), and Hansen (2014) take up Lucas's challenge by interpreting those high market prices of risk as indicating not high risk aversion but instead moderate amounts of aversion to model misspecification.

pair of papers express Lucas's opinion that the data indicate that the model fails to adequately integrate macroeconomic theory and value theory. What Lucas and others regard as inadequacies of his chapter 2 model have already led to fruitful efforts at integration and are bound to lead to more.[35]

1.11 *Optimal Fiscal and Monetary Policy in an Economy without Capital*

Although Lucas dismisses his chapter 2 asset pricing model in chapter 19, it still plays an important role in chapter 7's "Optimal Fiscal and Monetary Policy in an Economy without Capital" written with Nancy L. Stokey. The chapter 7 model embeds an extension of the chapter 2 model that gives the government an incentive to manipulate state contingent prices in light of its knowledge of the Euler equations that restrict asset prices. How the government ought to manipulate the prices of its debts and assets is an important part of devising an optimal fiscal policy in a closed economy. State contingent prices affect the value of a government's debts because marginal tax rates affect allocations and, via chapter 2-like asset pricing formulas, equilibrium state contingent prices. The Ramsey planner knows this.

A representative agent cares about the discounted expected utility of its consumption and leisure. There is a linear technology for converting labor into a single good; an exogenous stochastic process for government expenditures driven by a Markov process; a competitive equilibrium with distorting taxes; and a Ramsey planner who must finance government purchases by levying a flat rate tax on labor earnings and trading a complete set of history contingent securities. The government uses these securities to purchase insurance against high levels of future government expenditures from the private sector.[36] The timing protocol is important. The Ramsey planner chooses a history-contingent plan at time 0 and sticks to it. As usual in a complete markets economy, the plan can be implemented with all trades occurring at time 0 and a full set of Arrow–Debreu history-contingent securities. It can also be implemented with sequential trading of one-period Arrow securities or sets of j-period Arrow securities. All of these can implement the Ramsey allocation, and all require commitment of the Ramsey planner. Lucas and Stokey observe that ". . . the [Ramsey problem] has no clear counterpart in actual democratic societies. In practice, a government in office at time t is free to reassess the tax policy selected earlier, continuing it or not as it sees fit. To study fiscal policies that might actually be carried out under institutional arrangements bearing some resemblance to those that now exist, we need to face up to the problem of time inconsistency."

Lucas and Stokey approach the problem by implementing a Ramsey plan with a sequence of governments each of whose members is obligated to honor long-horizon Arrow securities that it inherits from last period's government but is free to set the flat rate tax. Lucas and Stokey show that there exists a term structure of long-horizon state-contingent government debt each period that induces a successor government to implement its period's Ramsey plan flat rate tax. Lucas and Stokey state that "Our interest in this case does not arise from features that are intrinsic to the theory, since the theory sheds

[35] For example, see De Santis (2007) for a refinement of the chapter 19 calculation that emphasizes the importance to the chapter 19 calculations of assuming that somehow idiosyncratic risks have been efficiently diversified. See Hansen, Heaton, and Li (2008) for a discussion of recent efforts to improve the chapter 2 model by altering both the stochastic consumption process and how the representative agent cares about it.

[36] These resemble arrangements between the U.S. government and the merchant marine or the railroads: subsidize in peacetime, nationalize during war time.

no light on why certain commitments can be made binding and others not, but because this combination of binding debts and transient tax policies seems to come closest to the institutional arrangements we observe in stable, democratically governed countries."

In contrast to outcomes in an earlier model of Barro (1979), as a consequence of complete markets, total government debt is not an independent state variable in Lucas and Stokey's model. Instead, government debt at any date is an exact function of the Markov state that drives government expenditures. This occurs, for example, because "a war-financing debt is repeatedly canceled as long as the war continues, and is paid off only when the war ends." An accompanying outcome is that the flat rate tax is not a random walk, but instead is also an exact function of the Markov state driving government expenditures. These features come from how the Ramsey planner trades state-contingent claims, markets that are missing in Barro's environment.

1.12 *Robustness of Predictions across Classes of Models*

Throughout the volume, Lucas wrestles with the following tension. Despite the fact that outcomes in models with frictions depend sensitively on many details, Lucas nevertheless wants general principles that can guide quantitative policy advice. My reading of a message from the menu-cost literature is that this is a tall order. But it is better to hear Lucas struggle with the issue than it is to hear me second guess him:

> [T]o paraphrase Tolstoy's observation about happy and unhappy families, complete market economies are all alike, but each incomplete market economy is incomplete in its own individual way. . . . Models of monetary economies necessarily depend on assumed conventions about the way business is conducted in the absence of complete markets, about who does what, when, and what information he has when he does it. Such conventions are necessarily highly specific, relative to the enormous variety of trading practices we observe, so monetary theories can give the impression of basing important conclusions on slender, arbitrary reeds. I think that this impression is exactly wrong, that the main implications of theories that attribute real effects to monetary causes by means of some form of price rigidity are largely independent of the way the rigidity is modeled or motivated. . . . [We now have a] list of theoretical examples that illustrate possible mechanisms through which monetary instability may induce inefficient fluctuations in economic activity. [In these examples] . . . it is only unanticipated movements in money that are predicted to result in inefficient levels of production and consumption. Each of these models that trace real pathologies to a combination of rigid prices and monetary unpredictability focuses on one specific source of the crucial rigidity: nominal contracting (Fischer 1977, Phelps and Taylor 1977), incomplete information about the current state of the system (Lucas 1972), a game that obliges sellers of goods to commit in advance to nominal prices (the present paper). All of these assumed sources of price rigidity have the important virtue of descriptive realism: people really do sign nominal contracts, people really do have seriously incomplete information about the state of the economy in general and the quantity of money (and where it is located) in particular, people really do put dollar prices on the goods they sell and live with these pricing decisions for non negligible time periods. All of the models we have that incorporate any one of these facts have the common implication that unanticipated monetary shocks have non-neutral, multiplier effects that are quite different in character from the real distortions that result from anticipated inflations.[37]

> We have a wide variety of theories that reconcile long-run monetary neutrality with a short-run trade-off. They all . . . carry the implication that anticipated money changes will not stimulate production and that at least some unanticipated changes can do so. Does it matter which of these rationales is appealed to? The answer to this harder question must depend on what our purposes are. Any of these

[37] From Chapter 12, "The Effects of Monetary Shocks When Prices Are Set in Advance."

> models leads to the distinction between anticipated and unanticipated changes in money, the distinction that seems to me the central lesson of the theoretical work of the 1970s. On the other hand, none of these models deduces the function ϕ [relating production to the money growth rate] from assumptions on technology and preferences alone. Of course, ϕ depends on such factors, but it also depends on the specific assumptions one makes about the strategies available to the players, the timing of moves, the way in which information is revealed, and so on. Moreover, these specifics are all, for the sake of tractability, highly unrealistic and stylized: we cannot choose among them on the basis of descriptive realism. Consequently, we have no reason to believe that the function ϕ is invariant under changes in monetary policy—it is just a kind of Phillips curve, after all—and no reliable way to break it down into well-understood components.[38]

1.13 *Financial Crises*

I would have included Atkeson and Lucas (1992) in this volume because, with a little imagination, that paper can be interpreted as a dynamic general equilibrium version of a Diamond and Dybvig (1983) model. Diamond and Dybvig describe a physical environment in which it is good for banks to offer deposits that insure a group of ex ante identical consumers against taste shocks for earlier or later consumption. They describe an equilibrium that supplies insurance efficiently under a particular exogenous first-come, first-serve bank deposit contract. The problem is that the equilibrium is not unique and that the first-come, first-serve deposit contract gives rise to inefficient equilibria with bank runs. By withdrawing early during bank runs, patient consumers don't truthfully reveal their types to society's mechanism for sharing risks between early and late consumers. Diamond and Dybvig show that government-supplied deposit insurance provides a cost-free way to prevent such behavior, eliminate bank runs, and assure efficiency. Deposit insurance succeeds by inducing all consumers truthfully to reveal their "type" (early or late) to the banks when withdrawing deposits.[39]

Atkeson and Lucas (1992) describe interactions among a collection of infinite horizon consumers who experience privately observed random taste shocks each period. A benevolent planner with access to risk-free loans from an outside source constructs a tax and transfer scheme for sharing risks that is incentive compatible in the sense that it induces each consumer truthfully to report his taste shock to the planner. The planner balances his wish to insure people against the need to provide incentives for truthful reporting. Atkeson and Lucas show that the optimal allocation rule has a recursive representation that uses each consumer's continuation value as a state variable. To induce truth telling, the planner decreases the continuation values of consumers reporting urgent wants for consumption today, while increasing continuation values of consumer's reporting less urgent wants today. This causes the distribution of consumption to spread out over time. Atkeson and Lucas provide a partial analysis of how to implement such an allocation with decentralized financial institutions, while Green and Lin (2003) approach how to implement an allocation uniquely.

Atkeson and Lucas (1992) was one of a small number of early papers that taught us how to use continuation values as state variables in order to harness dynamic programming to study settings with repeated moral hazard and/or enforcement difficulties.

[38] Chapter 16, "Nobel Lecture: Monetary Neutrality."

[39] In their concluding section, Diamond and Dybvig (1983) remarked that their paper did not study the types of moral hazard problems with deposit insurance that had concerned earlier researchers.

2. *Practicing Modern Macroeconomics*

Not everybody likes the type of formal macroeconomics and monetary economics that Arrow (1967) wanted and that, with vision and technical virtuosity, Lucas time and again supplied. Summers (1991) did not. Summers asserted that "progress is unlikely as long as macroeconomists require the armor of a stochastic pseudo-world before doing battle with the real one." But since the mid 1970s, many creative macroeconomists have ignored Summers and followed Lucas's lead in approaching both data and policy analysis with better and better estimable, simulatable, stochastic dynamic general equilibrium models.

Lucas taught that ". . . our interest in models . . . is whether their solutions can be constructed and characterized, given assumed behavior for the various shocks to the system,"—an interest determined by the purpose and structure of modern macroeconomic models, from which ". . . the main lessons, are first, the futility of trying to assess policy changes in terms other than changes in policy processes and, second, the impossibility of analyzing changes in monetary and fiscal processes independently of each other."[40]

Lucas wanted microeconomic foundations for practical reasons. Prescott and Lucas's calibration project aspires to use microeconomic studies to gather empirically credible values of key parameters governing preferences and technologies to import into a quantitative macroeconomic model: "This is the point of 'microeconomic foundations' of macroeconomic models: to discover parameterizations that have interpretations in terms of specific aspects of preferences or of technology, so that the broadest range of evidence can be brought to bear on their magnitudes and their stability under various possible conditions." (Lucas 1987, p. 46). In key papers in this collection, especially chapters 17, 19, and 20, Lucas artfully applies this vision about how to do quantitative macroeconomics. The literature on menu-cost models reignited by the Golosov–Lucas paper in chapter 20 is just one important example of an active research area that is being improved by successive specifications of models designed to use features of micro data to help understand responses of real and nominal aggregate variables to both systematic and surprise movements in monetary policy instruments.

Repeatedly, Lucas stresses the discipline and coherence enforced by general equilibrium models: ". . . it would not be useful for me simply to run through the various writings of these and other economists, taking one principle here and another one there: Major differences in the analytical frameworks they used would make it impossible to see which principles are mutually consistent and which contradictory, and it would be impossible to tell, at the end, whether we had arrived at a complete characterization of an efficient monetary and fiscal policy or only a partial one."[41]

Lucas plays by the rule that it takes a model to beat a model, and also by the rule that it takes an equilibrium model to pose a macroeconomic policy problem properly: "It may be that some day we will have an operational theory of business cycles that suggests additional, useful principles besides those I have discussed [in Chapter 9, "Principles of Fiscal and Monetary Policy"]. In the meantime, it seems sensible to me to take policy guidance from models we can actually understand and work through, not from models we wish we had, or models other people think we have."

Atheoretical pattern finding studies are important inputs into Lucas's work

[40] From Chapter 8, "Money in a Theory of Finance."

[41] From Chapter 9, "Principles of Fiscal and Monetary Policy."

on monetary theory, but in his chapter 15 review of Milton Friedman and Anna J. Schwartz's *A Monetary History of the United States, 1867–1960*, Lucas emphasizes "A *Monetary History* is full of numbers, but there are many quantitative questions to which its model-free approach cannot provide answers." And he notes that Friedman and Schwartz's informal style of analysis and presentation leaves important aspects of the *Monetary History* open to diverse interpretations: "For Romer and Romer, exogeneity is a property of a particular realization, while for Sims it is a property of a distribution: the two approaches are not the same. Friedman and Schwartz's discussion of independence is sufficiently unclear that both interpretations are defensible. So, too, is a third, which I prefer, which is that independence as Friedman and Schwartz use the term has nothing to do with statistical exogeneity, but means rather that whatever the sources of monetary contractions may have been, on average or in particular instances, the monetary authorities *could* have maintained *M*2 growth had they chosen to do so. It is independence in this sense that is, I think, conclusively defended by Friedman and Schwartz in detailed analysis of episode after episode." And it is this third interpretation that Lucas relies on when he says "I am persuaded by the evidence Friedman and others have marshalled that associates at least major recessions with monetary instability, so that I believe a monetary policy selected on the efficiency grounds I have discussed would, as a kind of by-product, be an adequate counter-recession policy."

Lucas eloquently explains how general equilibrium reasoning *matters*.

> The great disciplining virtue of applied welfare economics is that it forces one to take a position on all of the issues involved in constructing a quantitatively serious general equilibrium model of the entire economy. . . *everything* must be faced. In a monetary application especially, this can be a humbling experience because it lays bare the many really basic issues on which we are far from a solidly based understanding." Praising papers by Brock and Turnovsky (1981), Chamley (1981), and Summers (1981), Lucas describes how "Each of these papers replaced the savings function of the household with a preference function, the discounted sum of utilities from consumption of goods at different dates. Each used the assumption of perfect foresight, or rational expectations, to deal with the effects of future taxes on current decisions. . . all three contributions recast the problem of capital taxation in a Hicksian general equilibrium framework with a commodity space of dated goods. . . this recasting was not a matter of aesthetics, of finding an elegant foundation for things our common sense had already told us. It was a 180 degree turn in the way we think about policy issues of great importance.

Lucas is blunt in criticizing studies that require but lack a general equilibrium analysis: "We do not want to talk about the welfare cost of *price* movements, but rather of the cost of suboptimum policies. For erratic inflation, . . . Fischer's partial equilibrium approach and his failure to identify the *sources* of the price movements his representative household faces lead to ambiguities that make it impossible to apply his results to observed series. . . . I agree with Fischer that price variability has costs, but I think they can be analyzed only if viewed as symptoms of something else."[42]

3. *Concluding Remarks*

Lucas stated his vision of how to improve macroeconomics this way: "I see . . . progressive element in economics as entirely technical: better mathematics, better data, better data-processing methods, better statistical methods, better computational methods. . . . learning how to do what Hume and Smith

[42] From Chapter 17, "Inflation and Welfare."

and Ricardo wanted to do, only better: more empirically founded, more powerful solution methods."[43] The papers in this volume prove how Lucas delivered in ways that could not have been imagined when he began.

Throughout the volume, Lucas writes inspiring words about the history and purposes of macroeconomics: "Macroeconomics was born as a distinct field in the 1940s, as a part of the intellectual response to the Great Depression. The term then referred to the body of knowledge and expertise that we hoped would prevent the recurrence of that economic disaster. . . . macroeconomics in this original sense has succeeded: Its central problem of depression prevention has been solved, for all practical purposes, and has in fact been solved for many decades. There remain important gains in welfare from better fiscal policies, but I argue that these are gains from providing people with better incentives to work and to save, not from better fine-tuning of spending flows."[44] Doesn't that sound like Samuelson's neoclassical synthesis?

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[43] Chapter 16, "Nobel Lecture: Monetary Neutrality."

[44] Chapter 19, "Macroeconomic Priorities," published originally in 2003. Does the 2007–2008 financial crisis call for modification of Lucas's concluding sentence? I read the evidence marshalled in Calomiris and Haber (2014) as confirming Lucas's last sentence.

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