

Galbács, Peter

Working Paper

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CHOPE Working Paper, No. 2020-06

Provided in Cooperation with:

Center for the History of Political Economy at Duke University

Suggested Citation: Galbács, Peter (2020) : What did it mean for Lucas to set up "useful" analogue systems?, CHOPE Working Paper, No. 2020-06, Duke University, Center for the History of Political Economy (CHOPE), Durham, NC

This Version is available at:

<https://hdl.handle.net/10419/216757>

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WHAT DID IT MEAN FOR LUCAS TO SET UP 'USEFUL' ANALOGUE SYSTEMS?

BY PETER GALBÁCS

CHOPE Working Paper No. 2020-06

April 2020



What did it mean for Lucas to set up ‘useful’ analogue systems?

Peter Galbács

Abstract

This paper provides a look into what Lucas meant by the term ‘analogue systems’ and how he conceived making them useful. It is argued that any model can be regarded as analogue system provided it has remarkable predictive success. The term is thus neutral in terms of usefulness. To be useful, Lucas supposed models to meet further requirements. These prerequisites are introduced in two steps in the paper. First, some properties of ‘useless’ Keynesian macroeconometric models come to the fore as contrasting cases. Second, it is argued that Lucas suggested two assumptions as the keys to usefulness. One is money as causal instrument, and the other is the choice-theoretic framework to describe the causal mechanisms underlying large-scale fluctuations. It is also argued that Lucas advocated these presumptions for he conceived them to be true. Extensive quotes from Lucas’s unpublished materials underpin the claims.

Keywords: Robert E. Lucas, microfoundations, business cycle theory, rational expectations, island models

1. Introduction

One of Lucas’s key terms is analogue system. As Lucas argued, economics must aid in assessing the effects of alternative economic policy measures. Societies, however, are complex, and experimenting on them is expensive, dangerous and unethical. Economics thus must rely on various analogies.¹ Some of them are of historical character. If we know what

¹ Lucas expressed permissive ideas on analogies. For him, analogies are supposed to be useful for specific problems, including scientific puzzles, and to this end, no similarity between the target and the model is needed. As he argued, based on experiences we gained by using a given chair, we are justified to infer that we can replace a light bulb while standing on another one. What is more, this analogy supports us in extending these positive experiences to tables. If an analogy holds, it relates two different things (such as a chair and a table, or a

effects a given change triggered under specific conditions in a society, we can infer the effects of a similar change to expect elsewhere. The use of such analogies is limited as it is only effects of past events that we can speculate about. Economists can get around this obstacle by building mathematical models with analogies between reality and theory (Lucas, 1988/2011, p. 4). Analogy holds and renders a model an analogue system if the model performs well in imitating as closely as possible the time series behaviour² actual economies show during business cycles (Lucas, 1977, p. 11; 1980, p. 697).

Besides good empirical performance, there is a further requirement that has become an iconic feature of Lucas's economics: to place macroeconomics on microfoundations. Even if not from the very first times,³ it is at a young age when Lucas started showing intense interest in understanding aggregate level dynamics in terms of microeconomics. Setting the scene with his Ph.D. thesis (Lucas, 1964), in the mid-1960s he turned to the problem of the investment demand function and the investment behaviour of the optimizing firm (Lucas, 1965/1981; 1967a) and then to the dynamics of a competitive industry such firms constitute (Lucas, 1966/1981). Lucas (1967b) applied a two-step process in which he aggregated the individual supply functions of identical optimizing firms into the industry level to derive an industry-level supply curve and factor demand functions. The problem thus was the interplay between sectoral or aggregate output and firm-level decisions (Lucas, 1967c).

The problem soon shifted to the goods-leisure choice of the representative household to build an aggregate labour-supply function (Lucas & Rapping, 1969a; 1969b). Lucas (1972) placed such Lucas-Rapping households in a monetary setting to understand their response to

society and a model) behaving alike in similar situations (Hand-written notes. Lucas papers. Box 27. 'Adaptive behavior, 1985–1986' folder).

² When it comes to pinpointing the features models ought to mimic, Lucas (1977, p. 9) refers to those co-movements of aggregative time series that Mitchel (1913; 1927; 1951), Burns and Mitchell (1946) and Friedman and Schwartz (1963) aptly documented.

³ During his graduate studies, Lucas was involved in a research the aim of which was to estimate and test some quarterly aggregate consumption functions (Griliches, Maddala, Lucas, & Wallace, 1962).

stochastic shocks to the money supply and to conceive business cycles as the outcomes of agents' decisions. Later he turned the need for microfoundations into the fundament of his critique against the then conventional macroeconometric practice (Lucas, 1976; 1977; 1980). As he pointed out, without paying attention to how agents' decision rules change in response to policy interventions we have no chance for building meaningful models for policy assessment. Going farther, in the 1980s he envisioned the complete reduction of macro to micro (Lucas, 1987). Even though this extreme reductionist version is widely regarded as infeasible (Hoover, 2009; 2012), understanding macro-dynamics as the outcomes of decisions meant to Lucas the key to useful economics in the years he exerted the most profound influence.⁴

However, the nature of Lucas's microfoundations is contentious. De Vroey (2011; 2016, pp. 179-180) understands Lucas's analogue systems as mere fictions the aim of which is to mimic time series dynamics to save some selected phenomena of societies and, at the end of the day, to help us predict how an economy responds to certain shocks. De Vroey repeatedly underlines that Lucas's assumptions are always false. Likewise, Boumans (2005, pp. 92-96) claims that Lucas had nothing to do with assumptions beyond their ability to underlie good empirical performance. On this account, Lucas's assumptions, being unrealistic and belonging to the model worlds only, are purely of *as-if* character.⁵ Vercelli (1991, p. 130) also relates analogue systems to predictive performance and regards Lucas's assumptions as untrue propositions. By contrast, Hoover (1995) referring to Herbert Simon's influence on Lucas sees more in Lucas analogue systems than mere fictions. As Hoover argues, good predictions

⁴ Lucas's microfounded models of the 1970s are not in line with his subsequent reductionist suggestions (Galbács, 2020, pp. 172-190). In his models, agents sometimes directly focus upon the macro-level (Hoover, 2008, pp. 323-324): they are confused with global price dynamics, rational expectations are identified with the outputs of an overall macro-model, and the budget constraint for the agent is national income (Hoover, 2001, p. 228), in per capita terms. These models by no means implied complete elimination.

⁵ As-if assumptions have a long history in economics, with Friedman's positivist methodology as a most prominent example. For Friedman (1953/2009), assumptions, when used properly, help save the phenomena only, while the real properties of the modelled things are dispensable.

can admittedly live on unrealistic assumptions, though every phenomenon to be modelled implies a small set of real properties that are to be preserved in minimalist descriptions (Simon, 1969/1996, p. 8). Lucas's assumptions are thus unrealistic as to achieve good empirical performance one needs to pay attention only to a highly limited number of features.

In what follows it is argued that Lucas's assumptions are far more than useful fictions. Some of his unpublished works effectively underline that Lucas applied the idea of monetary-induced business cycles or the basic choice-theoretic framework as assumptions since they are true propositions—or at least Lucas conceived them to be true. First, Section 2 characterizes Keynesian macroeconometric models as useless analogue systems for they failed to trace large-scale fluctuations back to individual decisions. Section 3 points out that Lucas regarded money as the trigger of business cycles that worked through decisions of rationally optimizing individuals not for the sake of empirical performance but for the fact that agents really adjust to changing macroeconomic conditions by informed decisions. Section 4 offers concluding remarks.

2. Keynesian macroeconometrics as a negative example for analogue systems

To learn more about the crucial components of useful analogue systems, a viable strategy is to start with models that cannot but yield only useless knowledge (Lucas, 1976, p. 20).

Keynesian macroeconometric models provide an outstanding explanation for why empirical performance on its own is insufficient to underpin useful analogue systems.

A central thread of Keynesian macroeconomics has been a development leading from Keynes's qualitative theory to empirically testable models (Fair, 1992; De Vroey & Malgrange, 2016). Tinbergen (1939) and, treading in his footsteps, Klein (1950) and Klein and Goldberger (1955) played pioneering roles in this transition. By realizing that Tinbergen without Keynes was not rigorous and consistent enough and that Keynes without Tinbergen

could by no means be empirical and quantitative, Klein (1950, p. 1) created the prototype of empirically well-performing Keynesian macro-models. Even though model-based policy evaluation as a constituent concern of Keynesian theory emerged as a high-ranked objective for Klein (1947a; 1964) relatively early, in the beginning Klein regarded the understanding of large-scale macroeconomic fluctuations as the first problem to settle (Bjerkholt, 2014). Only after completing this stage and then having models with good empirical performance could he proceed in the post-war years to the assessment of alternative economic policy scenarios (Visco, 2014).

With time, however, predictive performance of Klein's models proved to be insufficient. Success emerged mainly in the short run (Ball, 1981, pp. 86-89), and despite this achievement, models contained some elements that kept performing terribly. Such a vulnerable component was the Keynesian equation that related price and wage dynamics to aggregate demand and the unemployment rate (Leeson, 1998, p. 78; De Vroey & Malgrange, 2012, pp. 132-133). As Christ (1956, pp. 390-408) highlights, this problematic wage-rate-adjustment equation had rather a bad fit, even if on the whole the Klein-Goldberger model had remarkable short-run predictive success. Finally, the high inflation and high unemployment period of the 1970s, which was difficult to interpret in the Keynesian framework, forced professionals to give up this cherished trade-off (Diebold, 1998, p. 178). Klein (1964, p. 20) admittedly had problems demonstrating that his extended demand-oriented Keynesian theory was capable of treating inflation as a complex phenomenon. However, he remained convinced that Keynesian models kept performing well even in the face of the alleged supply-side inflation shocks (Mariano, 1987, p. 441).

In a series of papers from the second half of the 1970s, Lucas, partly accompanied by Tom Sargent, explained why past empirical success fails to imply future reliability. Klein's wage-adjustment equation did not take expectations into account, and the whole system also

disregarded how expectations exert influence on behavioural rules (Valadkhani, 2004, p. 266). However, as Lucas argued, one cannot expect future predictive success as long as the conditional forecasts taking policy measures as model inputs pay no attention to the behavioural effects of economic policy and regard the superficial behavioural parameters as invariant (Lucas & Sargent, 1979, p. 6). If so, a detected unemployment-inflation trade-off inevitably extends to the long-run, which, as a violation the long-run neutrality of money, was the sequel that triggered Lucas's critique (Fischer, 1987, p. 16). By contrast, Lucas (1972; 1973) was convinced that the moment policy attempts to use the trade-off discretionally, it immediately starts fading away. Optimizing agents may change behavioural rules in response to changes in policy (Sargent, 1977, pp. 2-3). Economic analysis thus ought to dig down to the level of the genuinely stable economic primitives like taste and technology to predict policy-induced outcomes on this solid basis (Lucas, 1977, p. 12). Turning a blind eye to this peculiarity, Keynesian models cannot provide 'useful' information for economic policy discussions (Lucas, 1976, pp. 19-20). By pinpointing the theoretical failures of Keynesian macroeconomics, Lucas (1980, pp. 705-706) also explains why he has never accepted supply-side shocks as the rationale for the collapse of the Phillips-curve.

Lucas's invective against Keynesian macroeconometrics is abundantly recorded in the archives. In the excerpt below,⁶ very instructively, he discusses the case in the same 'useful-useless' dyad:

Keynesian economics – at least in its analytically explicit and operative Tinbergenian variant, which is the form that interests me – offered a way to go from a set of sample moments (variances, covariances, autocovariances – the whole multivariate world) to policy options available to society – “trade-

⁶ Lucas prepared these notes for his lecture at Ohio State University and his Marion O'Kellie McKay Lecture at the University of Pittsburgh, both held in 1980, so these drafts are from the same period as his misgivings published in the second half of the 1970s.

offs”. [...] We observe that government spending and unemployment have been negatively correlated in the past (think of WW’s I and II). We use this correlation to estimate the change in unemployment to be expected from an increase in government expenditure in the future. That’s all there is to the multiplier – there is nothing deeper. [...]

Difficulty is this: no reason to believe that correlations exhibited in past data will continue to obtain under new policies. Old correlations may contain no useful information on future trade-offs. I say “may” but situation is worse than this: now [we] know that multipliers for aggregate monetary, fiscal policy are useless. (Hand-written notes. Lucas papers. Box 13. ‘Lectures notes, 1979–80’ folder) (emphasis in original)

His arguments are nowhere near novel, but effectively summarized here. Although Keynesian models had remarkable empirical accuracy gauged against the sample periods, this fact fails to underpin reliability in times after policy interventions have broken past behavioural rules—not even in cases where a trade-off was detected as operative for a long time. This excerpt also tells a lot about analogue systems. Lucas (1980, pp. 696-697 and 704) refers to a wide range of theories as analogue economies, regarding any model having good imitation capacities as analogue theory. By this standard, Keynesian macroeconometrics also falls into this category (Lucas, 1977, pp. 11-12; 1980, p. 701). On this ground, Lucas in this draft could draw a sharp distinction between *useful* and *useless* analogue systems. In the case of behavioural changes triggered by policy interventions (or, in a broader context, any changes in the environment), previous trade-offs ought not to be expected to persist. Models

disregarding this particularity cannot reliable and *useful*, despite their showing good empirical performance otherwise.⁷ The term ‘analogue system’ is thus neutral in terms of usefulness.

In another paper, Lucas (1994) draws attention to the causal assumptions of the Klein-Goldberger framework as a further problematic aspect. Keynesian macroeconometric models of the 1950-60s generally presumed that large-scale fluctuations stemmed from shocks to private spending. From this it follows that macroeconomic depressions seemed to have diverse and opaque sources, while Keynesians made no efforts to pinpoint money supply as a single causal factor. As Lucas argues, this attitude was only a contribution to distracting attention from the monetary origins of business cycles. It was a mistake, he goes on, as it is exactly some monetary matters, the inflation dynamics of the 1970s, that highlighted the downsides of the Klein-Goldberger model.

Still in the 1970s, Lucas devoted a longer train of thought to the discussion of the casual failures of the Klein-Goldberger model. These arguments remained unpublished, but being highly illuminating they are worth quoting at length:

What are the causes of business cycles? This is not a very well-posed question (because “cause” is such a bad word) but it is [a] question that anyone trying to model economic time series has to ask, in one form or another. [...] The first attempt to deal with it in the context of an explicit economic model was in Adelman and Adelman’s simulations of Klein and Goldberger’s econometric model of the United States.

[...]

⁷ Lucas (1977, pp. 11, fn. 8) hastens to add that even atheoretical equations or systems of equations may have good fit on data (Snowdon & Vane, 2005, p. 287). These models, however, are also subject to Lucas’s critique, so they have only limited acceptability. On this basis, Lucas joined in a debate with Sims on vector autoregressive models. As Lucas pointed out, having no explicit theory is not a way out of the need for letting fixed parameters change (Galbács, 2020, pp. 127-134).

In the Klein-Goldberger system [...] there is a definite sense in which one can say that business cycles are caused by “autonomous” [...] fluctuations in various components of private spending. Since the variance of the error terms in investment equations are, in models of this type, much larger than consumption errors, one can sharpen the conclusion to the statement that business cycles are caused by autonomous fluctuations in investment demand. (Hand-written notes. Lucas papers. Box 13. ‘Barro, Robert, 1974, 2000, undated’ folder)

In general, models contain causal hypotheses, so different variables emerge in different models as triggers of business cycles. He goes on:

This substantive conclusion of Klein, Goldberger, Adelman and Adelman is, of course, of great interest [...]. Their work was also a great advance methodologically, or at least terminologically: A variable is said to cause business cycles (in the context of a particular, simulatable model) if setting its error variance equal to zero eliminates them in simulations. [...]

This notion of cause has the advantage of being fully operational. [...] If one can forecast the errors in the causative shock (and there is no presumption that causal variables in this sense are unpredictable), policies can be designed that will, in the context of the model, offset them. This is the Klein-Goldberger model, fluctuations in autonomous private spending flows can be offset by changes in taxes and government spending, stabilizing (though perhaps not fully) real output and employment. Of course, the prime motivation of Klein and Goldberger’s work was to gain the ability to do this. (Hand-written notes. Lucas papers. Box 13. ‘Barro, Robert, 1974, 2000, undated’ folder)

Here Lucas refers to the simulations Adelman and Adelman (1959) performed on the Klein-Goldberger model. The Adelmans first ran the model deterministically (i.e. without stochastic shocks) that resulted in a quick convergence towards an equilibrium real output. No sizeable oscillations, but a complete absence of business cycles emerged. Second, they built realistic variances upon the error terms for exogenous government spending components. Results bore close similarity to the outcomes of the deterministic session. Finally, they put realistic variances to the error terms for the private sector spending equations. In the latter case, variability in real output and employment similar to real-world fluctuations emerged. As Lucas argued, based on these results it was possible to draw the inference that business cycles could be eliminated in a Keynesian fashion via government spending or tax policies.

Being openly Keynesian, the Klein-Goldberger model is fiscally inclined as it contains several fiscal instruments as exogeneous variables (e.g. government expenditures, various taxes, etc.).

As De Vroey and Malgrange (2012) portray Klein's interests, his macroeconometrics took market failures as a fact of life, thus it was aimed at finding effective fiscal remedies.

Monetary policy is not treated in detail: it is bank reserves that show up in the model as the only monetary policy instrument. No surprise, Klein loved opposing fiscal and monetary policy. For him, there were a plethora of fiscal instruments ranging from direct government investments through the play with business taxes to income redistribution and running comprehensive social security systems by which governments could enhance private spending. By contrast, monetary policy seemed quite ineffective (Klein, 1947b, pp. 168-180). However, this is a conclusion and a policy suggestion Lucas harshly rejected.

3. The keys to usefulness: money and the choice-theoretic framework

To see why, we need to turn to the role money and individual decisions play in business cycles, and hence to the reason why macroeconomics needs microfoundations.

As for money, in his published writings from the 1970s Lucas time and again emphasizes monetary instability as the most plausible trigger of large-scale macroeconomic fluctuations. Referring to Friedman and Schwartz's (1963) *Monetary history*, Lucas took as a fact that there stood a strong correlation between money supply and nominal income, thus swings in the money stock, somehow defined, induced transient spending fluctuations and hence short-run changes in real output. At the same time, money proved to be neutral in the long-run, so it is only short-run non-neutrality that made it possible for real output and employment to fluctuate about their natural rates. As it is well-known, however, Friedman was very cautious applying the causalist terminology (Hammond, 1988, pp. 7-8), notwithstanding the causal chain seemed to point from money towards the real economy, and not the contrary (Lucas, 1994; Hammond, 1996).

Yet we can hardly find under Lucas's pen any statement about money as 'the' cause of business cycles. As Lucas (1977, pp. 13-14; 1981, p. 16) argues, Friedman provided no theoretical explanation to the natural rate theory either in the *Monetary history* or in his presidential address (Friedman, 1968). To unravel the causal role of money, Lucas needed a theory he placed upon the choice-theoretical framework that also made room for expectations. Occasionally, Lucas expresses his insistence on choice theory in powerful statements. He strongly believed that choice theory had no alternatives as agents adjust and respond to changes in the environment by making decisions (Lucas, 1981, pp. 4-7). By criticizing "traditional" macroeconometric models, Lucas (1976, pp. 26-26 and 41; 1977, pp. 13-14; Lucas & Sargent, 1979) also makes the case for paying attention to the individual decision problem. If a drawback stems from the neglect of the changes in behavioural rules, the use of the choice-theoretical framework provides a way out. Lucas (1977, p. 15) goes so far to say that to 'practice economics, we need *some* way [...] of understanding *which* decision problem agents are solving.'

Money and decisions are two ingredients of the one effective framework. Agents need to make a lot of decisions before they could gather all the necessary information, and they offset deficiencies in knowledge by forming expectations (Lucas, 1972). It is prices that agents use as the source of information, while price dynamics has both monetary and real sources. Money can thus contribute to the confusion agents face, and here lies the theoretical problem. To conciliate neutrality and non-neutrality, economics must show how decisions under imperfect information conditions differ from full-informed decisions (Lucas, 1972/1981, p. 92). The problem can only be settled in the choice-theoretical framework where money has a key role. The excerpt below well expresses Lucas's deep conviction about money as the only plausible trigger of large-scale fluctuations and that monetary causes work through agents' decisions:

There has been much scholarly dispute about Friedman and Schwartz's interpretation of the 1929-33 period, and given the difficulty of drawing causal inferences from nonexperimental data of this sort, perhaps this is unavoidable. But what are the other candidates? What possible forces, other than the well-documented monetary collapse, could have induced the millions of independent decision makers in this modern industrial economy to have reduced their joint production of goods and services by 34 percent over a four year period? If changes in the money supply did not induce these events, then something else did. What was it? (Typed notes. Lucas papers.

Box 13. 'Barro, Robert, 1974, 2000, undated' folder)

As Lucas points out, it is reality that suggests understanding business cycles in choice theory as a monetary phenomenon. It follows that even if the Klein-Goldberger framework assumes some spurious causes of large-scale fluctuations, it by no means implies that business cycles have no well-identifiable monetary origins (Lucas, 1981, p. 16).

It is still reality where the details of the decision problem come from—agents are influenced by money when making decisions on labour supply and production. As Lucas (1977, p. 16) puts it, ‘we know from much evidence’ the basic tendencies in decisions and the list of circumstances agents consider. Here Lucas provides only some sketchy remarks, but dwells upon the problem in some notes in the archives. In these lengthy fragments, as an introduction, first he repeats his insistence on the choice-theoretic framework which must be defined by assumptions in line with the evidence we have on individual decision making (Typed notes. Lucas papers. Box 13. ‘Barro, Robert, 1974, 2000, undated’ folder). Then he turns to some observable behavioural tendencies:⁸

We know, in the first place, that the wealthier people are the less hard they work. This can be seen by comparing rich to poor societies, the U.S. today, say, versus the U.S. a century ago or versus India today. People in rich societies enter the workforce later in life, retire earlier, take longer and more frequent vacations, and work shorter weeks [than] people in poor countries. Those with large non-labor incomes work less than others in the same society with lower income from capital. Leisure – defined broadly to include all activities other than working for pay – is a normal good.

In this description of reality there is a place even for unanticipated changes relevant to understanding individual reactions to surprise monetary policy shocks:

There is, at the same time, enormous latitude as to when one works. We concentrate our work effort in peak-earnings years: When leisure years are added, they are added at the beginning (a year or so of goofing off after or during college, say) or at the end (early retirement) when we aren’t worth as

⁸ Elsewhere Lucas also refers to lifelike agents. The theoretical portrayal of workers as decision makers that McCall (1970) or Lucas himself painted (Lucas & Prescott, 1974) is supposed to grab the essential features of the decision problem workers face (Lucas, 1987, p. 57).

much on the market as we are in our 30s and 40s. [...] Within the year, everyone concentrates his work effort during peak times. Workers in the construction trades substitute winter for summer vacations. People in retailing work long hours in December, short hours in July. Academic journal editors work harder in the summer, when their colleagues are free enough from teaching duties to write up and submit their results.

Unpredictable peaks have the same effects as predictable seasonals.

Everyone in a manufacturing establishment works long hours when a big order comes in unexpectedly: vacations are postponed, people don't get "sick" as often, overtime hours are put in [...].

As a further characteristic, employees dislike too frequent switches between different activities:

A third feature of observed work patterns is that people like work (and leisure) time to come in chunks. We like fifteen vacation days in one three week period, not scattered through the year. We put in forty hours in five eight hour pieces, not seven six hour days, or twelve siesta-broken half days. Even within a day, we like blocks of time: writing in the morning, teaching and committee busywork in the afternoon. There are setup costs, large (like a two-hour commute or a three day drive to the Rockies) and small (like the fifteen minutes it takes to get back into a problem one hasn't thought about for a while) that make it wasteful to change activities too frequently. (It is in the allocation of time that the convexity beloved by economists is most obviously violated: no one prefers a convex combination of eating, sleeping, working and watching TV to any of the extreme points over a ten minute period, though we all do over a week and most of us would over a day.)

The micro-level insights with which Lucas fed his economics were obvious and evidently given parts of the socio-economics universe:

These three features of working life – the increasing demand for leisure as wealth increases, the willingness of people to substitute over time so as to concentrate work effort in high return periods, and the fixed costs of activity switching that induces in to work and consume leisure in stretches of time – are well known to anyone who walks through the world with his eyes open. We do not need econometricians to “test” these observations. Neither do we need theorists to determine whether this sort of behavior follows from standard axioms of rational behavior: It is perfectly easy to imagine a rational agent who reacts to a windfall wealth increase by working harder, or who likes to allocate his time by engaging in hundreds of different activities every microsecond.

This is a very complex problem, however. The good thing is that, as Lucas (1986, p. S401) argues, there is no need for us to pay attention to all aspects of behaviour. In the related drafts, Lucas provides a more detailed reasoning:

it is clearly not a serious strategy [...] to try to model any process of decision making by codifying all that is really going on. Even the most detailed “protocols” compiled by questioning decision makers [...] about their thought processes capture, and are intended to capture, only a tiny fraction of what is in fact being thought. [...]

Any operational model of any decision making process [...] will necessarily be highly abstract – it will leave almost everything out. (Typed notes. Lucas papers. Box 27. ‘Adaptive behavior, 1985–1986, 2 of 2’ folder)

Theory is supposed to focus upon only a petite part of the decision maker, while other aspects are superfluous. In summary:

Trying to model explicitly this entire [decision making] process, really an entire human personality, would surely be a lunatic enterprise and I do not propose to undertake it. (Hand-written notes. Lucas papers. Box 27.

‘Adaptive behavior, 1985–1986, 1 of 2’ folder)

Referring to Simon’s (1969/1996) distinction between the way an agent actually works (i.e. his inner environment) and what he does (i.e. his outer environment), Lucas in these fragments claims that minimalist, rudimentary or super-abstract descriptions of the former will do when it comes to understanding the latter. Using the example of a company, Lucas sheds light on why we do not need to know much:

The question involves the way a large collection of people—a corporation—alters its decisions in response to changes in its environment. Yet the economic answer makes no reference to who these people are, how they are organized to interact, who in the group is responsible for which decisions. My guess is the most economists, even specialists in investment theory, have no idea what goes on in the accounting, legal or financial department of a business firm. (Typed notes. Lucas papers. Box 27. ‘Adaptive behavior, 1985–1986, 1 of 2’ folder)

Only those elements of the inner environment *must be* preserved as true propositions that are really indispensable and key to modelling a given aspect of the outer environment—everything else *must be* left out.

Lucas’s strategy is thus to find the core choice problem in its simplest form that suits a given theoretical puzzle. In reality, the labour supply decision, Lucas’s foremost interest, is

dependent upon current and expected real wage through a number of channels. For instance, the real wage affects the child-bearing decisions hence population size; the participation rate; and the number of hours an employee offers as his labour supply (Lucas & Rapping, 1969a, p. 726). A worker resolves this allocation problem by making decisions.⁹ What is more, the labour supply decision is a part of a multi-dimensional setting. When making his labour supply choice, the worker may be assumed to consider a lot of different activities: work, leisure time, job search or even sleeping and eating (Lucas, 1981, p. 4). However, Lucas identifies the core problem in how current and expected wages and prices affect current and future consumption and leisure (Lucas, 1972/1981, p. 92). Likewise, given the direct link between employment and output with an unchanging technology, there was no need for Lucas (1972) to model labour supply and production as outcomes of distinct decisions. Output dynamics can entirely be traced back to changes in the labour supply.

At the same time, Lucas leaves no doubt that his key assumptions regarding the conditions of the decision problem come from reality. In this respect, two letters are most instructive. The one is related to Shiller's (1984) review on Lucas and Sargent's (1981) compilation. Shiller's assessment of the 'rational expectations revolution' was rather lukewarm in the paper. He admitted that the rational expectations approach had become the chief principle in empirical macroeconomics, though he remained sceptical. By behaviourist standards, it seemed an eccentric, if not bizarre, assumption as it attributed more to economic agents than they were factually capable of. Information is expensive to collect and process in the quantity necessary

⁹ In turning choice theory to business-cycle modelling, especially in emphasizing how optimizing agents substitute expectations for information deficiencies (Lucas & Sargent, 1979, p. 8), Lucas received inspiration from Phelps (1970). A part of Phelps's prototypical application was the case for regarding informed decisions as a real basis of the adaptation mechanism agents run (Phelps, 2007, pp. 544-545). In his Nobel-bio, Phelps (2006) makes an even clearer manifesto, saying that he was one of those 'who wanted macroeconomic models to have lifelike actors whose expectations and beliefs were causal forces'. In Chicago, Becker (1976, pp. 13-14) and Stigler (1946, pp. 13-14; 1979, p. 3) also argued for the interpretation of neoclassical choice theory as a highly realistic description of the core of human behaviour.

for acting rationally, so people rely on simple heuristics, which they only infrequently modify.

Lucas replied in a letter:

You have got to be right [...] that “most individuals behave in accordance with simple rules of thumb which are only rarely reevaluated.” It has always intrigued me that Muth hit on his formulation at Carnegie Tech at the time when “behavioral” economics was at [its] peak there. In the introduction to his original paper, Muth [...] insists that his hypothesis does not assert that rationality characterizes the “scratch work of entrepreneurs.” Whatever may be said of his successors, I think it is crystal clear that Muth was trying to push “rationality” to an extreme not in naive ignorance of parallel behavioral work, but in full knowledge of it, at the then current center of behavioral work in economics.

Muth was right I think, that what promise economic theory offers is precisely guidance as to what will happen at those [rare] points at which people are compelled by events to reevaluate the rules of thumb they use. At such points, the kind of codified rules of thumb psychologists record are useless. Your point that economics is bad psychology is well taken but it does not follow that psychology is good economics. (Lucas’s letter to Robert J. Shiller. February 16, 1983. Lucas papers. Box 5, ‘1983, 2 of 2’ folder)

Lucas calls into game the flip side of the usual behaviourist arguments. Experimental psychology draws a distinction between the slow and fast forms of thinking (Kahneman, 2003; 2011). In normal times intuitive fast thinking provides reliable decision schemas agents follow in their automatic operations—this is the way of thinking Shiller refers to. However, there are cases where such rules turn out to be wrong and following them proves

inefficacious, thus slow thinking must intervene by overruling—this is the point Lucas makes. Here Lucas offers a behaviourist context to interpret the way he applied the rationality assumption. When agents need to adjust to policy actions, prior rules become outdated (Lucas, 1976) and agents must act rationally to find their new rules of thumb. By the same token, discriminating between nominal and real price signals also requires rationality, even if agents do not have the time necessary for relying on slow thinking (Lucas, 1972). It is beside the point whether rationality dominates everyday behaviour (it does not) as Lucas applied it to cases (changes in the social setting) where routine actions are suboptimal, and where rationality has no alternatives. And in such instances, rationality works in reality. Results in experimental economics further strengthen this argument. Vernon Smith and others showed how agents thrown in an unknown environment make rational efforts to build up the rules of behaviour (Smith, Suchanek, & Williams, 1988, p. 1148; Caginalp, McCabe, & Porter, 2003, pp. 4-5).

The other letter is from a correspondence with Costas Azariadis, Lucas's former doctoral student at Carnegie Tech (1969-73). In his letter of October 19, 1976, Azariadis objected to a technical nuance of the island metaphor that randomly allocates producers across the markets. For Azariadis, it seemed nonsense to assume an agent located on a market with favourable demand conditions to be ready to leave. Instead of the spatial dimension, Azariadis suggested the distribution of demand over time. In his reply Lucas explained what the metaphor actually meant:

One has to take my spatial set-up metaphorically or it is crazy. By “forcing” people to leave good markets, I just wanted to capture the fact (which I think is obviously present in reality) that there are transitory demand and supply shifts. (Lucas's letter to Costas Azariadis. October 25, 1976. Lucas papers. Box 3. '1976, 1 of 2' folder)

This is a representational code in the sense Shech (2015; 2016) applies the term. Even if a model contains wholly fictitious or idealizing assumptions (Psillos, 1999, p. 29; Chakravartty, 2007, pp. 187-192), it is still possible to represent existing parts, mechanisms or aspects of reality. To this end a representational code is needed that clarifies what part of reality is highlighted by which part of the related model. Such codes thus also aid in circumscribing the sets of meaningful inferences. A code instructs users how to interpret the model, so some possible inferences come to be unsound—like the inference that strings of swings are massless just because they are assumed to be so in theory (Contessa, 2007). Accordingly, here Lucas precludes the most obvious reading, and establishes the representational relationship between an aspect of reality (transitory shifts on markets) and his model (reallocating agents between markets). As a result, a fictitious detail can represent a key element of reality.¹⁰

4. Conclusions

In this paper, I have argued that Lucas regarded predictive success as only one requirement useful models must meet. Lucas also insisted on regarding money as the trigger of large-scale fluctuations and on the use of the choice-theoretic framework—these are his further requisites. When specifying his key assumptions, Lucas paid special interest to the core aspects of the relevant facet of reality, monetary-induced business cycles as outcomes of individual decisions. Empirical success thus did not take priority over other requirements. On the contrary, Lucas expected his approach to lead to successful models due to his success in seizing the real causal processes in highly abstract ways. The results above thus contribute to the clarification of Lucas's methodological principles and emphasize his ambition to latch onto the way reality works.

¹⁰ It cannot be taken for granted that every fictitious assumption involves an appropriate representational code. For tractability reasons Lucas (1975) assumed that expectations are pooled among traders, so the average values describe all agents' predictions. Lucas was highly dissatisfied with this solution and regarded it as temporary only (Lucas's letter to Edi Karni. October 18, 1976. Lucas papers. Box 3. '1976, 1 of 2' folder).

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