Equilibrium Modeling in Economics:

A Design-Based Defense

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Abstract

Several authors have recently argued that the excessive focus on equilibrium models in mainstream economic analysis prevents economists from providing accurate representations of the complex and dynamic nature of real economic systems. In response, this paper argues the following. Many economic systems are the products of deliberate and centralized human design. People can and do build and support structures, such as social institutions, aiming to enhance the predictability of economic systems, and thus to move them towards being equilibrium systems. This provides a reason to think that many economic systems can be represented by equilibrium models.

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I. Introduction

Many authors argue that mainstream economics' excessive focus on equilibrium models prevent it from providing accurate representations of the complex and dynamic nature of real economic systems (see e.g. Vromen, 2001; Young, 1998; Groenewegen & Vromen, 1999; Hodgson, 1999, pp. 258-260; Lawson, 2006; Galla & Farmer, 2013; Berger, 2009; Buchanan & Vanberg, 1991; Carlaw & Lipsey, 2012, pp. 736-737). The aim of this paper is to clarify and respond to this criticism.

More specifically, the paper shows that there are reasons to think that many economic systems are, in fact, often well-represented by equilibrium models. First, equilibrium systems tend to more predictable, in the medium- to long-term, than non-equilibrium systems. Second, predictability in the medium- to long-term matters to economic actors; they are therefore incentivized to take steps to ensure that the systems they are interacting with are equilibrium systems. Third, economic actors are frequently able to carry out these steps: through explicit or implicit system design. From these facts, it can be concluded that there are good reasons to think that many economic systems are in fact equilibrium systems. In this way, it becomes possible to provide one reason for why equilibrium modeling in economics can be defended after all. This reason, though, does not lie in hitherto overlooked features of the models themselves, but in the fact that the target systems of these models are special. Many—though not all—economic systems are the product of the right kinds of (more or less deliberate and centralized) human design: for example, auctions are often deliberately designed to have stable and predictable outcomes. In contrast, unstable economies often see capital flight, thus furthering their instability and making their continued persistence less likely. These more or less deliberate and centralized processes of design can yield economic systems that are, in fact, equilibrium systems.

The paper is structured as follows. Section II makes the relevant notion of equilibrium modeling more precise. Section III presents the common criticism surrounding the use of equilibrium models in economics and makes clear how it is best understood. Section IV lays out the design-based defense of the use of equilibrium models in economics. Finally, section V concludes.

II. Equilibrium Models in Economics

There are many ways to characterize the notion of "equilibrium model," in economics and in general. Indeed, on a sufficiently broad understanding (e.g. one that includes perturbation modeling), virtually any model can be understood as an equilibrium model (see e.g. Bonnans & Shapiro, 2000; Dixon, 1990; Milgate, 1987). However, in the present context, a narrower—but still sufficiently encompassing—notion is pertinent. According to this understanding, equilibrium models are model systems that (a) eventually settle into a stable state—i.e. a state to which the system returns if it is moderately perturbed—and (b) this stable state is the fulcrum of prediction and analysis of the model's target system (see also Samuelson, 2002, pp. 57-58; Carlaw & Lipsey, 2012).[1] There are several further points that need to be noted about this notion of equilibrium.

First, this characterization differs from some others mentioned in the literature that emphasize some of the features of specific economic systems, such as the existence of a "balance of forces" (Arrow & Hahn, 1971, p. 1; Robinson, 1956, p. 57; Chipman, 1965) or the fact that the relevant

[1] Note that this thus focuses on an "ontic" sense of equilibrium modeling, rather than a purely formal one (Lawson, 2005; Backhouse, 2004).

actors have consistent, true beliefs (Hayek, 1937, p. 44).[2] The present analysis is more general: while some equilibrium economic systems may indeed feature a balance of forces (whatever exactly that means) or yield mutually compatible true beliefs, not all need to do so. For example, while (Bayesian) Nash equilibria may well be seen as classic economic equilibrium systems, not all economic equilibrium systems need to be reducible to the former.

Rather, the focus here is on the general features of *predictability* and *determinateness*. Specifically, what matters here is just that equilibrium models differ from non-equilibrium models—sometimes known as “complex” or “dynamic” models—in *not* exhibiting chaotic behaviors in at least a subset of their relevant dynamics.[3] In the latter models, there is no fixed set of states that the model system tends towards; rather, the system may be at any of an array of indefinitely many states, depending on subtle differences in initial conditions (see e.g. Werndl, 2009; Strevens, 2005; Benhabib, 2008). Furthermore, these states are not states that the system will persist in—with the important exception of trivial states that amount to the collapse of the system. An example of such a model is one based on a random walk: a discrete quantity $q_t \in \mathbf{Z}$ undergoes a step-change at every time period, with the probability P of this change being positive being determined by a simple rule like $P(q_{t+1} > q_t) = 0.5$. Depending on where the system starts, the probability of ending up at any given state will differ, and the system does not approach or return to any given state (other than the trivial, collapsing states of $+\infty$ and $-\infty$). It is such *inherently unpredictable* model systems that are excluded here.[4]

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[2] For some very lucid discussions of these different equilibrium concepts, see e.g. Lawson (2005); Backhouse (2004).

[3] Further distinctions among full and partial equilibrium systems could be made, but this is not so relevant here. See also Benhabib (2008).

[4] Note also that an equilibrium model’s stable state could be a level quantity (the market clearing price of a commodity) or a rate of change (a country’s GDP growth rate).

Note that this way of understanding equilibrium systems also has some significant historical pedigree. For example, Arrow and Hahn (1971, p. 1) state that the notion of "general equilibrium" used in economics can be characterized as "the simple notion of determinateness, that the relations describing the economic system must be sufficiently complete to determine the values of its variables." Arrow & Hahn's conception here explicitly emphasizes predictability (point (b) above): knowing the relations—i.e. the equations—underlying the systems is sufficient for knowing where the latter will be at any given time. Further Machlup (1958, p. 9) notes that "[e]quilibrium, in economic analysis [is] a constellation of selected interrelated variables so adjusted to one another that no inherent tendency to change prevails in the model which they constitute." This clearly speaks to point (a) above: equilibrium systems are systems with a stable state. Finally, Robinson (1956, p. 59) indirectly brings both of these points together when she notes that:

> "Nor can we apply the metaphor of a balance which is seeking or tending towards a position of equilibrium though prevented from actually reaching it through constant disturbances. In economic affairs the fact that disturbances are known to be liable to occur makes expectations about the future uncertain and has an important effect on any conduct (which, in fact, is all economic conduct) directed towards future results."

I return to some key elements of the first sentence of this quote in section III, but the key point to note here is just that Robinson sees economics as committed to equilibrium systems that are predictable through their stable states in a way that non-equilibrium systems are not.

The second point to note about the present notion of equilibrium system is that it is permissive with regards to the exact way the stability of the relevant stable states is spelled out: it could require global stability, local stability with separate basins of attraction, or merely the fact that perturbations are bounded.[5] Similarly, the present notion of equilibrium system is consistent with different constraints on the length of time within which systems reach their stable states: some systems may reach their stable states quickly, some may do so more slowly, and some may only do so in the limit (as in the famous—converging—cobweb models: Ezekiel, 1938; see also Justus, 2008a). While, in general case, there is much to say about this kind of variability, for present purposes, it is not of major importance—though it is a point to which I return below.[6]

Again (and as will be made clearer in the next section, too), the key thing here is that equilibrium models have a *predictable directionality*: they move towards a stable state. It may be true that the longer it takes for a model system to reach a stable state, there will often be less certainty about the immediate movements of that system—there may be less "bite" to the stabilizing forces here.[7] However, the key point here is that equilibrium systems have at least *some* directionality. While it may not be possible to state exactly how the system will behave in the immediate short-term, and while the exact end-state of the system may only be probabilistically predictable, we have at least a sense of the overall direction in which an

[5] For more on the different stability concepts, see e.g. Justus (2008a). Note also that, generally, in situations with multiple equilibria, the point at which the basins of attraction meet is an unstable equilibrium. Terminologically, the kind of equilibrium where the system only needs to return to a point within a given proper subset of its state space—thus making its "stable state" really a region of state space centered on a given state—is sometimes said to involve "resistance" (Justus, 2008a). A classic (if very weak) example of this kind of case is provided by the concept of Lyapunov stability. A state is said to be Lyapunov stable if, for every bounded neighborhood one cares to specify, a neighborhood of perturbations can be found that ensures that the future states of the system will remain within the specified bounded neighborhood. For criticisms of this equilibrium concept, see Justus (2008b, 2008a).

[6] The limiting sense of stability is provided by systems that contain (sets of) states in which the system will remain *unless* it is disturbed. In the rest of the discussion, though, these unstable equilibria will not play a major role, so a further discussion of them is not necessary here.

[7] Though it is also true that the development of some equilibrium model systems is easy to predict despite only reaching their equilibrium in the infinite limit—as is the case for the converging cobweb model (Ezekiel, 1938)

equilibrium system is moving.[8] Whether it reaches that stable state is less important than the fact that it displays movement *towards* it.

The third and final clarification to note here concerns what it means for a model system's stable states to be the fulcrum of the model's analysis (i.e., part of (b) of the above characterization of an equilibrium model). This was implicit in Arrow & Hahn's statement "that the relations describing the economic system must be sufficiently complete to determine the values of its variables," but it is also explicitly pointed out by Dow (1996, p. 111), who notes that equilibrium analysis works by imposing "some order on complex relationships" (see also Backhouse, 2004, p. 301).

To make this clearer, it is best to briefly consider one of the paradigmatic models of economics: the Solow growth model (Jones, 2002). This model has not only been theoretically and empirically very influential in analyses of economic growth, but it is also often taught to new economic students as a clear example of how economic modeling in general works (Jones, 2002; Halsmayer, 2014). While the actual content of the model is not central in what follows (though section IV returns to questions concerning economic growth briefly), what does matter is that this is the *type* of analysis that is underlies equilibrium modeling in economics.

In the model, levels of GDP are assumed to be determined by a three-input production function—capital (K), labor (L), and a labor-modifying technology (A)—with the inputs being characterized by decreasing returns to scale. Labor and technology are assumed to grow at fixed rates n and g, and capital is assumed to accumulate as the difference between a fixed savings

[8] The fundamentals of this point also hold for situations in which there are multiple equilibria—e.g. in certain strategic, game theoretic models (Samuelson, 1998). By themselves, these models only allow prediction of where the model will *not* end up; to determine more precisely which equilibrium the system is heading towards, further assumptions can—and often are—added to the base model (Schelling, 1960; Samuelson, 1998; Leeson et al., 2006). In either case, though, it is true that equilibrium models have a directionality, and thus predictability, that non-equilibrium models lack (Galla & Farmer, 2013).

component (sY) and a fixed rate of capital depreciation (dK). This implies that, sooner or later, capital per technological-augment worker ($\tilde{k} = K/AL$) will stop accumulating. At this point—the equilibrium of the model—GDP per head ($y = Y/L = A\tilde{y}$) will grow at a rate that is equal to the rate of technological progress g.

Importantly, it is precisely this equilibrium growth rate that is then used to analyze the behavior of the economy at various time slices. For example, if there is an external shock to the system (such as a government stimulus in the face of a global pandemic) that makes capital investment more attractive (thus raising s to s'), an economy at equilibrium will grow until a new equilibrium at $\tilde{k}^{*}$' is reached. Given the assumptions of the model, it can be predicted that there will be a temporary boost in growth that gradually falls back down to the equilibrium growth rate of g.

In this way, the model can be used to describe what happens if the economy is *not* in its stable state. The economy's growth rate temporarily jumps to a value that is greater or lower than the equilibrium rate g, but then gradually falls back to the latter. The model thus makes clear in what direction and manner (gradually or instantaneously, etc.) the relevant economic variables change. It is in this sense that the model's stable state—the equilibrium growth rate—is used as the fulcrum through which an understanding of the growth dynamics of actual economies can be provided: the economic system is seen as *moving towards* its equilibrium states, and to do so in a specific way (laid out by the model).

Importantly, exactly this kind of analysis is typical of many other economic models as well. Mainstream economic modeling, in general, can be well characterized by the attempt to represent a given real economic system with an equilibrium model, and then analyzing that model's equilibrium states and their perturbation dynamics to provide a lens through with the economic system can be understood (see e.g. Mas-Colell et al., 1995; Varian, 1992; Blanchard, 2007; Arthur, 2015). Of course, non-equilibrium models are employed in economics, too (see e.g. Gähde et al., 2013; Helbing, 2013). However, it is undoubtedly true that a major proportion of work in economics is based on equilibrium models (Hausman, 1992; Mäki, 2013; Reiss, 2013).

III. Criticizing Equilibrium Modeling in Economics: A Clarification

Despite its ubiquity, though, the use of equilibrium models in economics has sometimes been challenged. For example, Arthur (2015, pp. 3-4) notes that:

> "[The] equilibrium shortcut was a natural way to examine patterns in the economy and render them open to mathematical analysis. […] But there has been a price for this equilibrium finesse. […I]t posits an idealized, rationalized world that distorts reality, one whose underlying assumptions are often chosen for analytical convenience."

Similarly, Nelson and Winter (2002, p. 24) write:

> "[S]tandard neoclassical theory cannot deal adequately with the disequilibrium dynamics involved in the kind of competition one observes in industries like computers or pharmaceuticals or, more broadly, with the processes of economic growth driven by technological change."

The concern behind these criticisms is that many or most of the target systems in economics are systems that are not generally equilibrium systems—and that representing them as such is therefore not plausible. It is the goal of this section to make these criticisms more precise. This is needed, as some versions of these criticisms actually turn out to be easily rebutted, whereas others are not, and require further discussion.

First, representational accuracy is not the only—and not necessarily even the most important—factor in determining a model's scientific cogency. Economic models, like all scientific models, are also chosen for other reasons. Prominent among these reasons is the model's computational ease and tractability, its simplicity, its predictive success, and its use as a standard or benchmark with which some phenomena (or other models thereof) can be assessed (Levins, 1966; Orzack & Sober, 1993; Weisberg, 2006; Potochnik, 2017; Batterman, 2009; Morrison, 2015; Weisberg, 2007; Samuelson, 2002; Massimi, 2018; Ray et al., 2015). Thus, whether real economic systems are or are not equilibrium systems need not entail much about whether *equilibrium modeling* in economics is compelling. Equilibrium models may have other redeeming features that outweigh their (supposed) representational inaccuracy.

For example, Jhun (2021) argues that equilibrium models can function as "epistemic scaffolds" that hold together models at different economic scales. While such multi-scale modeling may ultimately yield explanations of dynamic economic behaviors, the appeal to equilibrium models here is tied to their role in *holding together* multi-scale modeling, and is not itself to be given a representational gloss. Similarly, we may follow Friedman (1953) and use equilibrium models to the extent that they make accurate predictions, but otherwise not commit to the representational accuracy of their assumptions. For example, we may model the growing patterns of a sunflower by assuming it seeks to maximize access to sunlight, and that it therefore turns to face the sun. Such a model can be predictively accurate—though it does not accurately describe the mechanisms underlying sunflower growth. Similar points can be made about equilibrium models in economics.

Put differently: Arthur (2015) (among others) may be right in noting that equilibrium modeling in economics “posits an idealized, rationalized world that distorts reality”—but it may also be the case that these distortions are outweighed by the “analytical convenience” they provide, or that these models have some other benefits (epistemic scaffolding, predictive accuracy). However, this point about model-based (social) science, while true, should not be seen to fully diffuse the above criticism of equilibrium modeling in economics.

On the one hand, given the computational advances made possible by contemporary technology, some aspects of this kind of the defense of equilibrium modeling may end up lacking cogency. For example, it is not clear (to say the least) that, given today’s computers, chaotic and dynamic models are really intractable in a way that equilibrium models are not (Helbing, 2013; Symons & Boschetti, 2012). Hence, it is not clear that equilibrium models still have a leg up in terms of their “analytical convenience.” Relying on the non-representational benefits of equilibrium models is therefore not clearly a strong basis on which to build a defense of the latter.

On the other hand, even to the extent that the above points continue to be true, this is not where the discussion here should be seen to end. Whatever other uses of equilibrium models in economics may have, it should not simply be granted that they necessarily *must be* representationally inaccurate. Indeed, as made clearer in the next section, this is far from obviously true. Given this, an appeal to non-representational virtues of scientific models fails to fully get at the issues here: while equilibrium modeling in economics may *also* be justifiable for a host of non-representational reasons (though, as just noted, this is not so straightforward either), this does not mean that it is *only* justifiable in this way. The representational accuracy of equilibrium models is an open question that deserves to be looked at in its own right.

The second caveat about the above criticism of equilibrium modeling in economics that needs to be noted here is that this criticism cannot just be that real economic systems are rarely or ever at an equilibrium, and that *this* is the reason why equilibrium models are representationally inaccurate. Equilibrium models do not represent economic systems as ones that are *at* an equilibrium—only as systems that have an equilibrium *towards* which they tend to evolve. Indeed, as the sketch of the Solow model above shows, the interest of equilibrium modeling is often precisely in determining what happens when the system is not at an equilibrium (see also Samuelson, 2002, pp. 58-59). The Solow model makes clear how an economy *responds to* external shocks (e.g., if s changes to s'): in this case, there are quick, temporary changes the economic growth rate that then gradually taper off. In this way, the model is useful for informing us about the direction in which important economic variables change, how long this change is, etc. The model is not just meant to represent economic systems that actually are *at* their equilibrium.[9]

For these reasons, the above criticism must be read differently. This criticism must be read as suggesting that equilibrium models in economics are representationally inaccurate due to the fact that real economic systems do not even *have* significant equilibria. The claim has to be that it is not just the case that these systems are not *at* an equilibrium—but that they do not even tend to move *towards* an equilibrium.[10] Put differently, the point made by Arthur (2015) and Nelson and

[9] Some economic models—such as the classic Walrasian ones—lack compelling dynamics (see e.g. Fisher, 1983; Walker, 1987). However, this is not true of all equilibrium models. At any rate, the present defense of equilibrium models is restricted to those models that do have such dynamics—a set which is at least not insignificant. I thank an anonymous referee for useful discussion of this point.

[10] A slightly weaker version of this criticism is that, while actual economic systems have equilibria, they are subject to such frequent shocks that they act *as if* they had no stable states. For present purposes, it is not necessary to distinguish the weaker and stronger versions of the above criticism.

Winter (2002) (and other arguments like these) should be seen to be that equilibrium models "distort [economic] reality" for positing that reality is centered around *equilibrium dynamics*—not for positing that reality is "static."[11] As Lucas (1980, p. 708) notes: "[t]he idea that an economic system in equilibrium is in any sense 'at rest' is simply an anachronism."

Indeed, the quote of Robinson (1956, p. 59) noted in the previous section is very clear on this point:

> "Nor can we apply the metaphor of a balance which is seeking or tending towards a position of equilibrium though prevented from actually reaching it through constant disturbances. In economic affairs the fact that disturbances are known to be liable to occur makes expectations about the future uncertain and has an important effect on any conduct (which, in fact, is all economic conduct) directed towards future results. […] The metaphor of equilibrium is treacherous."

Read like this, this criticism has some initial plausibility. On the one hand, it is clear that economic systems are characterized by the interplay of many different variables (Benhabib, 2008; Buchanan & Vanberg, 1991) and that there is a lot of change and movement in these systems (Nelson et al., 2018; Nelson & Winter, 1982). This makes it at least prima facie reasonable that these systems are complex, dynamic systems that lack an inherent directionality. One way to see this is in terms of the Sonnenschein–Mantel–Debreu results (Sonnenschein, 1973; Mantel, 1974; Debreu, 1974). These results show that it is easy to get non-equilibrium

[11] Note also that much work in thermodynamics also uses equilibrium models—but it would not be plausible to fault this work due to the fact that the universe is not in thermodynamic equilibrium. Equilibrium thermodynamic systems are inherently unrealistic. I thank Craig Callender for useful discussion of this point. See also Jhun (2021) and the contrasting perspective in Smith and Foley (2008).

macro-dynamics even with relatively "clean," equilibrium-model-conducive micro-assumptions (Mas-Colell et al., 1995, pp. 598-606). In other words, it is not too difficult for a set of micro-level interactions to combine in such a way that they yield complex, dynamic systems without an inherent directionality (Kirman, 1992, 2006). Given this, it is theoretically warranted to have at least a critical attitude towards the representational accuracy of (macro-) economic equilibrium models.

On the other hand, economic modeling in general has a very mixed record of success (at best). Given that most of this modeling is based on equilibrium analyses, this at least suggests that the assumption that economic systems are equilibrium systems may be mistaken. After all, since we cannot observe economic systems directly, the success of economic modeling—and thus, by implication, equilibrium economic modeling—would seem to be our best guide towards the nature of economic reality. Given that this success is far from unequivocally positive, it is not unreasonable to conclude that real economic systems may well not be equilibrium systems.

Of course, as is well known, economists work under some important epistemic limitations (Scriven, 1956; Machlup, 1961): in particular, key data (e.g. about individual preferences or decision making biases) may be unattainable for ethical or practical reasons. In turn, this means that the success of equilibrium economic models (or any other type of economic model) cannot be seen as a direct reflection of the nature of economic reality.[12] Still, even taking these points into account, the predictive and explanatory success of mainstream economic modeling—or, rather, the lack thereof—does not clearly speak in favor of this modeling tradition being based on representationally accurate assumptions (Rosenberg, 2012; Carlaw & Lipsey, 2012). Many such models fail to make fully accurate predictions, and there is much that these models fail to

[12] This also holds in the other direction: as noted earlier, equilibrium models may be predictively reasonably successful despite being representationally inaccurate.

anticipate. While this *could* be due to the epistemic difficulties faced by mainstream economic modelers, it does at least suggest that a closer look is warranted at whether it is the equilibrium approach that is to blame instead.

For these reasons, the idea that much economic modeling rests on fundamentally mistaken assumptions needs to be taken seriously. At least prima facie, it is not unreasonable to think that the difficulties with equilibrium modeling in economics rest on the fact that this kind of modeling simply misrepresents the nature of the underlying economic processes.

IV. Equilibrium Models in Economics: A Defense

As it turns out, though, there are some important reasons to think that equilibrium economic models are not inherently representationally inaccurate. Importantly, though, these reasons are not based some hitherto overlooked aspects of the practice of economic modeling (as is argued by e.g. Jhun, 2021), but on overlooked aspects of real economic systems. In particular, it turns out that there are some good reasons to think that many economic systems are equilibrium systems after all. At heart of these reasons is the fact that economic systems often are the—more or less deliberate or centralized—products of human thought. Economic systems often are shaped by us.[13] We do not need to take them as given, but can alter them, at least to some extent, as we see fit. (As will be made clearer below, this is not true to an equal extent for all economic systems; however, as also noted below, it is true for some such systems some of the time.)

[13] There is a sense in which this *is* a methodologically-focused defense: it is based on the idea that social science methodology is unique in that the objects of study (us) can change their behavior as a result of their being studied. This is the famous point about "reflexivity" in social science: Romanos (1973); Woolgar (1988); May (1998); see also MacKenzie (2008); Boldyrev and Ushakov (2016); van Basshuysen (2022). For a general philosophical treatment of the use of models to shape reality, see Tee (2019). A related notion is that of "performativity" (Guala, 2016; Brisset, 2019): by following the conventional rules of how to use and manipulate a model, researchers bring the model into being. I thank an anonymous referee for discussion of this. See also below.

Echoing some of the points made in the introduction, the idea here is this. (1) Equilibrium systems tend to more predictable, in the medium- to long-term, than non-equilibrium systems. (2) Economic actors want their economic systems to be predictable in the medium- to long-term, and therefore want the systems with which they are interacting to be equilibrium systems. (3) Through explicit or implicit system design, economic actors are frequently in a position to act on these wants. Hence, (4) there are good reasons to think that many economic systems are in fact equilibrium systems. Premise (1) of this argument was the subject of section II, and thus does not need to be further discussed here. It is premises (2) and (3) that need further elucidation and justification.

Starting with premise (2), note first that there are good reasons to think that, where economic actors are able to alter economic systems, they would prefer to alter them towards being equilibrium systems. To see these reasons, recall that it is in the nature of non-equilibrium systems that, in the medium- to long-term, they are less predictable than equilibrium systems (Robinson, 1956, p. 59; Dixon, 1990; Milgate, 1987; Machlup, 1958; Arrow & Hahn, 1971; Werndl, 2009): their behavior is less bounded and does not tend towards specific parts of state-space, but evolves largely in an undirected manner. At least in many cases—a point to which I return below—this makes these systems less attractive to interact with than equilibrium systems.[14] Indeed, this thought has been expressed very clearly already by Hayek (1976, p. 12):

> "What reconciles the individuals and knits them into a common and enduring pattern of society is that […] they respond in accordance with the same abstract rules. What […] enables [..] men to live and work together in peace is that the pursuit of their individual ends and the

[14] This is not to say that equilibrium systems need to be fully or easily predictable. The point is just that they are more easily predictable than non-equilibrium systems.

particular monetary impulses which impel their efforts […] are guided and restrained by the same abstract rules. If emulsion or impulse tells them what they want, the conventional rules tell them how they will be able and allowed to achieve it."

This preference for stability and predictability stems from the fact that, for actors in an economic system, the future states of that system typically are key factors to consider when making decisions.[15] However, in non-equilibrium systems, it is at best only possible to (probabilistically) predict the system's states in the very near future (though, depending on the details of the case, even this may be impossible); states in the farther future become mere guesswork (Robinson, 1956; Werndl, 2009).[16] By contrast, in equilibrium systems, the "fundamentals" underlying the systems—their equilibrium states and their relevant dynamics—provide grounds for planning for a much more extended future. Such planning is crucial for many economic decisions, though—at many different levels.

So, policy makers contemplating appropriate stimulus packages in the light of the covid pandemic needed to assess the inflationary and debt pressures these packages create in the future, as well as their impact on employment and poverty rates. Central bankers setting interest rates need to assess how these rates will affect saving, consumption, and investment decisions into the future. Producers managing supply chains need to assess how changes in these supply chains will

[15] Hayek prefers the terminology of "order" to that of "equilibrium" (Hayek, 1967, p. 184; see also Vaughn, 2013; Vaughn, 1999; Hudik, 2018). However, in the present context, this difference is not so important: the key here is just that it is reasonable to see economic actors as having a preference for stability and predictability, and that equilibrium systems—as they are understood here—provide this kind of stability and predictability.

[16] So, in an autocorrelated random walk, I can at most probabilistically predict that the variable will be tomorrow about where it is today (if there is little autocorrelation, I cannot even do that). For this reason, the point here is not that all predictable systems are equilibrium systems; rather, it is that equilibrium systems have a kind of directionality that allows predictability in the medium- to long-term; chaotic (non-equilibrium) systems are unpredictable in this regard. (As also noted above, it is precisely this longer-term predictability that matters for many aspects of economic decision-making.)

affect the product deliveries in the future—and given the complexity of contemporary supply chains, these effects can extend quite far into the future. Saving and consumption decisions are also clearly sensitive to future states of relevant economic system. An agent deciding whether to purchase or rent a home will find much easier to make this decision if they can have a sense of what interest and rental rates will be like at various points in the future. At heart of all of these widely accepted and quite basic points is the fact that economic decisions tend to have consequences that extend into the medium- to long-term future.[17]

Hence, the more agents can estimate these consequences, the easier their decision-making becomes. Improvements in such estimation can turn decisions under uncertainty into decisions under risk, and decisions under risk with greater variance to those with smaller variance—and thus, to less risky decisions (see also Taylor, 2003). Apart from cases of gambling or short-term speculation, lower-risk decision-making Pareto-dominates higher-risk decision-making: with more precise estimates of future states of the economic environment, agents have more information that they can use to decide what to do.[18] In short: due the fact that equilibrium economic systems are more predictable than non-equilibrium economic systems, it is plausible that humans would generally *prefer* to interact with equilibrium economic systems than non-equilibrium economic systems.

There is also some direct evidence bearing on these points. There is a relatively large literature showing that uncertainty about various factors affecting an economy—including, in particular, uncertainty about policies or the fundamental facts underlying a company or

[17] Note that these points are independent of the rational expectations hypothesis: to be sure, a Bayesian rational decision maker will take future states of the economy into account when making decisions. However, the point in the text is that the same is true for other decision-makers, too: it is a fact of everyday ordinary life that the future consequences of our decisions matter for our choices.

[18] This is in fact a straightforward consequence of understanding "information" here in the classic Shannon terms (Shannon, 1948).

industry—affects investor sentiment. As uncertainty about the future states of the economy increases, long-term investor confidence in the economy seems to decrease (Qi et al., 2022; Phan et al., 2021). Indeed, these preferences are also revealed by the fact that increased in political uncertainty correlates with greater economic instability: economic agents are more prone to leave economic systems at short notice if they are unsure about where the economy is heading (Qi et al., 2022; Smithson et al., 2019; Calford, 2020; Phan et al., 2021). Indeed, this is a particular instance of the much documented case of uncertainty aversion (Epstein, 1999; Smithson et al., 2019; Calford, 2020): apart from cases of explicit short-term speculation for its own sake, people engaged in medium- to long-term decision-making are willing to incur losses if it leads to decreases in uncertainty.

Importantly, furthermore, there is also reason to think that there are several different paths through which these preferences can affect the structure of an economic system. That is, there are several different ways in which we, as economic agents (and thus as parts of the very systems studied by us as economists) can take unpredictability out of the systems within which we interact, so that they are more likely to become equilibrium systems.

Most straightforwardly, sometimes, we as economic actors can simply *leave* non-equilibrium economic systems in favor of equilibrium economic systems. For example, foreign investors can pull their resources out of economies that behave erratically, and in which future states are highly unclear, and instead invest in economies that have a clearer directionality. Such foreign capital flight can be and has been a major cause of the collapse of certain economic systems, and thus lead to a sorting process (Kant, 1996; Cuddington, 1986). The upshot of this kind of process will be that the economic systems that actually persist will be equilibrium ones—non-equilibrium systems will end up going extinct (Robinson et al., 2005). This point is also borne out by some of the studies mentioned above: policy uncertainty decreases investor sentiment, and thus can lead to capital flight (Qi et al., 2022; Phan et al., 2021). In turn, this makes these systems less stable, and therefore more likely to collapse. Over time, we can thus expect the occurrence of a shift in the set of economic systems towards equilibrium systems.[19]

However, while there is no reason to think this kind of sorting could not be a significant source of pressure towards these systems being equilibrium systems, it should not be seen to be the only such source. Indeed, economic system sorting bleeds into the next type of process by means of which people's preferences for equilibrium economic systems influence these systems: economic system engineering.

This second set of cases concerns economic systems (or parts thereof) that are intentionally designed so as to be predictable, stable systems (see e.g. Bergemann & Morris, 2005; Hurwicz, 1994; Smith, 1976). In such cases, suitably situated economic agents—policy makers or central bankers for example—take deliberate steps that lead an economic system to becoming more stable and predictable (see e.g. Ofek, 2001; MacKenzie, 2008; van Basshuysen, 2022). (The reason that this situation and that of economic system sorting can bleed into each other is due to the fact that policy makers and other economic agents may alter economic systems that are under pressure from fleeing investors and other economic agents, so as to make them more stable and to prevent this flight.)

While it is not fully known exactly which kinds of institutions lead to particularly stable economic systems, it is widely agreed that, on a macro-level, well defined property rights, efficient processes for settling contractual conflicts, and low levels of corruption are key aspects

[19] Whether this is a selective process in the evolutionary biological sense depends on the account of selection adopted: on most of these accounts, the answer is no, as it does not involve reproduction (Godfrey-Smith, 2009). However, on the recent—though also somewhat controversial—account of Doolittle (2014), the answer is yes: on the latter, there can be selection even in a population of one. However, settling this dispute does not matter here.

of such institutional arrangements (Assenova & Regele, 2017; Acemoglu et al., 2001; Reinhart & Rogoff, 2009). At certain times and places, these kinds of institutions were set up precisely so as to ensure that they yield economic systems that are stable and predictable—i.e. which have stable, steady-state growth rates (Robinson et al., 2005; Acemoglu et al., 2001).[20] Indeed, these institutions were partly designed using paradigmatic equilibrium models like the Solow Growth Model (Halsmayer, 2014). This thus exemplifies the sense in which these models can be "performative" (Guala, 2016; Brisset, 2019; see also Morgan, 2012): the world is made more of an equilibrium system *through* the application of these very models. Something similar holds for financial markets, which were partly designed precisely to be the kinds of systems that match equilibrium economic theorizing (MacKenzie, 2008). It even applies to various specific marketplaces, such as the US's "National Resident Matching Program (NRMP)" which places recent graduates from medical school in residence positions in hospitals, and which was designed to create mutually desirable outcomes (van Basshuysen, 2022).

Interestingly and importantly, though, there are also known cases of economic system design that do *not* lead to more stability and predictability, and might in fact lead to *instability*: for example, the construction of 5-year plans that detail production quotas in planned economies led to instability and shortages. A plausible reason for this is in the fact—noted e.g. by Hayek (1937, p. 44)—that, in most cases, the generation of stable system requires more knowledge and information than could be obtained or used by one or a small number of people.[21] Corrosive colonial institutions are also unlikely to yield stable and predictable systems: these institutions

[20] More specifically, Acemoglu et al. (2001) show that mortality rates in the colonial period are useful instrumental variables for the estimation of GDP / head differences *now*. The reasoning behind this is that, in places where European colonizers found living conditions that suited them (and where they thus faced lower mortality rates), they set up "non-extractive"—that is stable, predictable, local growth-enhancing—institutions, and vice-versa.
[21] Advances in computing technology and AI may alter this conclusion, but for now, it still stands.

were built to extract as many as resources as possible in a short amount of time, with no regards their medium to long-term consequences (Robinson et al., 2005; Acemoglu et al., 2001).

It is thus not *all* bouts of economic system engineering that create stable systems; the engineering has to be of the right kind. This is important to emphasize: there is no reason to think that economic system engineering must necessarily lead to stable economic systems. Whether it does so in a particular situation depends on the particulars of that case: whether the engineering is done in the right way. Still, the important point here is that there are such kinds, and that they are being put into use. However, this is a general feature of all forms of engineering: not every way of building a bridge is one that can actually carry the appropriate weight in the appropriate circumstances. Some bridges, unfortunately, do collapse. However, mostly they do not. This is not an accident, but a result of the fact that they are designed to be stable, and that such design is typically successful. In other words, the fact that economic system engineering only contingently and fallibly leads to stable economic systems does not point to a deep problem in the argument here—though it does need to be acknowledged. (I return to this issue below.)

While these large-scale cases of institutional design are relatively rare, narrower instances of economic mechanism design are more common. A particularly good example of this is auction design. As shown by Galla and Farmer (2013), even quite simple strategic, repeated interactions with learning can lead to chaotic dynamics—though they can also lead to equilibrium dynamics (see the appendix for a more detailed statement of Galla & Farmer's argument). What this shows is that there can be no a priori expectation that a randomly chosen two- (or more) player-game will be an equilibrium one. Since auctions are precisely such strategic interactions involving learning—and thus examples of the games studied by Galla and Farmer—this thus implies that there are good theoretical reasons to think that the bidding behavior in auctions might well end up following a chaotic, unpredictable path, rather than aiming at a clear equilibrium outcome. Put differently: if auctions are not carefully designed, it is quite plausible that they will yield chaotic outcomes similar to the model described in Galla and Farmer (2013). (Indeed, a similar point is also made by Plott, 1997.)

This can cause major problems in situations where assets of major social value—such as telecommunication spectrum licenses—are to be auctioned off. To avoid the inefficient or insufficient distribution of such assets (after all, we as a society have an interest in ensuring public information is provided to as many people as efficiently as possible), governmental and private agencies are well advised to engineer spectrum auctions so that they have predictable, efficient outcomes, rather than having unknown outcomes. It is thus not surprising that much work has gone into doing exactly this. Through a combination of experimental work, models, and instantaneous adjustments, auctions have been and are designed that yield stable and predictable outcomes (see e.g. McAfee & McMillan, 1996; McMillan, 1994; Plott, 1997; Guala, 2001; Klemperer, 1999, 2002; Alexandrova, 2006; van Basshuysen, 2022).

For example, in the case of the US spectrum auctions of the 1990's, the group of economists in charge of designing them first tried out different auction designs in specially created experimental situations (Plott, 1997). These experimentally discovered designs were then further refined, as individually stabilizing auction rules can lead to unpredictable outcomes when combined (Plott, 1997; Alexandrova, 2006). For example, since spectrum licenses have complementary values (having one makes having another more valuable), it was found that simultaneous bidding on multiple licenses can lead to unpredictable and highly inefficient bidding cycles (Plott, 1997).[22] Such bidding was thus excluded.

[22] Indeed, the team of economists even monitored the auctions in real time to ensure that if problematic actions—such as cyclical bids—occurred, the auction could be stopped or altered.

In short: the auctions we tend to *actually* encounter in the world—as opposed to all the auctions we could *theoretically* encounter—are likely to be equilibrium systems. Auctions, especially for socially important goods, often are carefully designed so to be predictable systems tending towards a narrow set of states. In this way, it becomes reasonable to model actual auctions with equilibrium models in a way that it would not be the case if they were simply randomly drawn from the set of all the possible auctions. As shown by Galla and Farmer, many of the latter are *not* equilibrium systems. However, the actual auctions we are likely to encounter in the world are a non-random sample from the set of all possible auctions: they are biased towards equilibrium systems, simply because we made them to be so.

However, these forms of deliberate and centralized forms of economic engineering should also not be seen to exhaust the ways in which economic systems can be shaped to be equilibrium systems. The final—and probably most common—form of economic engineering sits between deliberate mechanism design and decentralized economic system sorting. These are cases where individual economic agents take steps to make an existing economic system work better *for them*—with the upshot being that the system turns into an equilibrium system. That is, in these cases, well-designed equilibrium economic systems are unintended consequences: they are not as such the target of the agent's decisions but are a concomitant result of these decisions nonetheless.[23]

A good example of this kind of case concerns traders in a market who look for technologies that make interacting in that market more predictable and reliable *for them*—such as mobile phones (Aker & Mbiti, 2010). These traders might not think about the market becoming an equilibrium system as they decide to invest in communication networks that link them to nearby

[23] Put differently, the arguments here apply to both what Hayek calls "cosmos" (spontaneous, grown order) and what he calls "taxis" (explicitly, consciously designed order): see Hayek (1973).

markets. Rather, these traders might just want to avoid bringing goods to market that, for no apparent reason, suddenly fail to sell, or to bring too few goods to markets with high demand. By investing in mobile phone networks, a trader can find out that prices for their goods are lower in market A than in market B, and thus bring their wares to the latter, and not the former. In turn, this means consumers in both markets can be more assured of adequate supply. The upshot is that unpredictable fluctuations in the market have been dampened.

Other examples of this kind of phenomenon can share an outward resemblance to the situation of intentional mechanism design—only that the *source* of this mechanism design is different here. In particular, people might *vote* for (or otherwise build up) social institutions like well-defined property rights and non-corrupt legal systems. However, they might do so not because they directly seek to build up equilibrium economic systems, but because social institutions like well-defined property rights and non-corrupt legal systems help *these actors* achieve their immediate goals, such as a more successful business, or a secure place to live. I might care about ensuring my right to my house is properly respected—not for the sake of creating a stable economy, but so that I can use my house as collateral for loans. This can lead me to vote for policies enshrining well-defined property rights into law. The upshot, though, will be similar to the cases of explicit mechanism design: a more stable, predictable economic system overall.

In the background of these cases is the fact that it is often in the interest of individual economic agents to take steps that reduce uncertainty and randomness. Often, this will involve increasing communication and transportation capabilities: such capabilities allow agents to avoid needing to guess what the best decisions is. In turn, this can have knock-on effects on other agents: if producers know where prices are highest, they can bring their goods to those markets. This will increase supply there, and consumers can know that, whichever market they happen to go to, the supply of the good present is more likely to match demand—rather than the markets being subject to the unpredictable boom-bust cycles that characterize non-equilibrium dynamics. However, the consumers or producers do not need to know or care about the latter point—they may just care about taking unpredictability out of the system for their own purposes. Still, the upshot of this will be an overall increase in the stability and predictability of the system.

In this way, this type of case combines the elements of the first and second cases. Due to the same sort of uncertainty aversion and desire for predictability mentioned in cases economic system sorting, people take steps to design economic systems to make the more to their liking (as in cases of institutional or auction design just mentioned). However, here, it is not the whole system that is designed—just some parts of it. Still, the upshot is a predictable system—a "spontaneous order" in Hayek's terminology.

In short: while it is true that economic systems involve a complex array of interrelated variables, there are reasons to think that humans can and do take steps, in a more or less centralized and deliberate manner, to shape these systems into equilibrium systems (see also Boldyrev & Ushakov, 2016; van Basshuysen, 2022). Because of this, it is plausible that many actual economic systems will likely be equilibrium systems—and that therefore the representational accuracy of equilibrium models in economics should not, per se, being seen as a weakness. Two further implications of this conclusion need to be noted.

First, a direct implication of this is that the failures of equilibrium models in economics are not always to be found in their representational accuracy. That is, whatever faults these models have, the fact that they are equilibrium models should not be seen to automatically count against them (this thus contrasts with the perspective e.g. in Carlaw & Lipsey, 2012). In particular, the view that some of the empirical problems of these models may rest in the epistemic constraints on economic modeling (such as limited data) gains some credence here.

Second, it is important to note that it is *not* an implication of the above arguments that *all* economic systems are likely to equilibrium systems. It is specifically economic systems that have been sufficiently long and sufficiently strongly the subject of the kinds of design forces sketched above that are likely to be equilibrium systems. As noted earlier, not all of the possible ways of shaping economic systems lead to increased stability and predictability (e.g. the five-year-plans of planned economies do not), and even those that do take time to influence the system.[24] This is especially so when it comes to the third situation above—unintended cases of economic system design. The decisions of a few traders to develop communication networks to assess prices in neighboring markets may not greatly increase the stability of domestic markets in general and scaling up these communication networks may take time.

On top of this, as noted earlier, the behavior of economic systems may be very unpredictable in the short-term, despite having a long-term direction (especially if it involves multiple equilibria: see also note 8). For example, it is famously the case that short-term stock fluctuations are highly unstable and hard to predict; in the short-term, most stock markets follow a random walk. In the long run, though, there may well be a steady-state growth rate to stock markets. This fits to the above arguments in that many economic actors are attracted to entering the long-term stock market to the extent that it is stable (e.g. through participating in mutual funds). The short-term market, by contrast, is of interest to speculators precisely because they are looking for a

[24] In a somewhat parallel situation, it has been found that explicitly designed pro-social incentives sometimes "crowd out" existing, intrinsic pro-social motivations, and thus end up being counter-productive (see e.g. Bowles & Polania-Reyes, 2012).

risky gamble—and it thus faces less pressure to be an equilibrium system (see also MacKenzie, 2008; Taylor, 2003).

In this sense, the present defense of equilibrium modeling in economics is only partial. While some economic systems plausibly are equilibrium systems, this is not true of all such systems. However, this does not make the defense uninteresting or insignificant. On the one hand, it is still important to note that *some* economic systems plausibly are equilibrium systems, and that therefore equilibrium modeling is *sometimes* representationally accurate. On the other hand, the present defense makes predictions about *which* economic systems are likely to be well-modeled using equilibrium models—and these predictions differ from some claims made in the literature. In particular, the argument here suggests that systems that have been shaped for longer and with more compelling tools—mobile phone networks, governmental regulation, no central planning, etc.—are more likely to be equilibrium systems, at least over long timespans. Importantly and contrary to Nelson and Winter (2002), this plausibly includes industries like computers and pharmaceuticals. While it is too early to tell how these predictions will match the empirical data, this at least shows that the present argument has significant methodological force.[25]

A last point worth making here is that the argument of this paper is not meant to imply that all stable economic systems are "good" in a broad sense. There can be (and are) highly stable totalitarian regimes, and there can be (and are) highly stable economic systems with much inequality (for example). While these may still be systems that are desirable for economic agents for providing them with predictability and stability, they are still *bad* in a different sense—e.g.

[25] It is also important to note that the arguments do not necessarily translate to other contexts of equilibrium modeling. For example, there is also a significant discussion concerning equilibrium modeling in ecology (Pimentel, 1961; Elton, 1958; Garnder & Ashby, 1970; May, 1972, 1974; Nunney, 1980; Justus, 2008a). However, since ecosystems generally are not human-designed in the ways in which economic systems are—though there can be exceptions (see e.g. Mitsch, 2012; Odling-Smee et al., 2003), defending equilibrium analyses there might need to rely on other considerations (see e.g. Galla & Farmer, 2013; see also Tee, 2019).

morally or politically. More generally, consider the one-shot Prisoner's Dilemma: this is an equilibrium system, but where the equilibrium is suboptimal in many regards (though it is predictable).

This again makes clearer the scope of the present argument. The predictability and stability of an economic system, while desirable as such, do not imply that the system is desirable *all things considered.* Whether a particular equilibrium economic system is one to actually aim to bring about depends on more than just the fact that it is an equilibrium system—our moral and political commitments are key elements to consider, too. Indeed, it is not even the case that being an equilibrium system is a *minimal requirement* for which economic systems to engineer: sometimes unpredictability may be a price worth paying, at least temporarily, to achieve a more desirable economic system. Rather, the point here is just the more restricted one that one of the key things that people often look for their economic systems is predictability and stability—and this therefore provides us with *a reason* to think that equilibrium economic modeling is often a compelling methodological approach. While this is thus only a restricted, partial defense of equilibrium modeling, it still is sufficiently substantive to be worthwhile noting.

V. Conclusion

A major—and classic—concern regarding contemporary economic methodology involves its overreliance on equilibrium models: i.e. models that analyze an economic system by focusing on the states that it will eventually settle into and to which it will return if disturbed. In order to address worry, I have argued that there are design pressures that lead economic systems towards being equilibrium systems. Since these systems are often shaped by more or less deliberate and centralized human intervention, they have been altered so as to be equilibrium systems. For this reason, the mere fact that many economic models represent economic systems as equilibrium systems should not, per se, be seen to speak against the former. Apart from being inherently interesting, this point also clearly brings out the extent to which research in the social sciences is "reflexive"—i.e. the extent to which the objects of study can alter their behavior in light of their being the subject of the study.

Appendix: Summary of Galla & Farmer's (2013) Model

At each stage of Galla and Farmer's model, two players pick a move out of a set of N possible moves with probability:

$$(1)\quad p(t)_M^A(t) = \frac{e^{\beta Q(t)_M^A}}{\sum_{i=1}^{N} e^{\beta Q(t)_i^A}},$$

where $Q(t)_M^A$ is a measure of the attractiveness of move M to player A at time t. (A parallel assumption to (1) is made for player B.)[26] Further, $Q(t)_M^A$ (and similarly $Q(t)_M^B$) is updated according to the following rule:

$$(2)\quad Q(t+1)_M^A = (1-\alpha)Q(t)_M^A + \sum_{i=1}^{N} \Pi_{M,i}^A\, p(t)_i^B\ ,$$

where $\Pi_{M,i}^A$ is the payoff to player A of playing move M against player B's move of i. This updating rule considers the attractiveness of a move in the past and weights this attractiveness by the extent of the player's memory (α) as well as the move's expected current payoff.

After randomly assigning payoffs (by drawing them from a normal distribution) and varying the degree of correlation Γ in the payoffs, as well as parameters α (the "memory" of the players) and β (the attractiveness of prior successful moves), Galla and Farmer (2013) find that a large number of the resulting set of games fail to have stable states, but are instead characterized by chaotic dynamics. In particular, they show that, for competitive games (where $\Gamma < 0$), a large set

[26] In Galla & Farmer's (2013, p. 1232) description of the learning dynamics, they at times appear to switch the labelling for players and moves. The description in the text appears to do justice to what is intended, though.

of parameter values lead to chaotic, non-equilibrium dynamics of the game. They further show that this is even more likely to occur when more than two players are introduced (Galla & Farmer, 2013, p. 1235).

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