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Abstract

In a recent article (Lawson, 2013), Tony Lawson argues for a Veblenian interpretation of the term "neoclassical", according to which a neoclassical economist is one whose methodology is at odds with their ontological presuppositions. This leads him to categorize many heterodox economists as neoclassical on the basis that their use of mathematical modeling is at odds with their (implicit) acceptance of an open-systems ontology. The reason is that, according to Lawson, mathematical modeling is deductivist: it presupposes that social systems are closed. The argument advanced in this paper is that this last claim is true only some of the time, and problematic only some of the time that it is true. It therefore amounts to a defense of mathematical modeling by heterodox economists that is, at the same time, sympathetic to Lawson's claims that the social realm is structured but open and that this ontology is (implicitly) accepted by many heterodox economists.

JEL codes: B41, B50, C02

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1 Introduction

According to Lawson (2013), based on his reading and advocacy of Thorstein Veblen's original use of the term (Veblen, 1900), many heterodox economists (as much if not more so than most mainstream economists)

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are properly categorized as "neoclassical". This is obviously a provocative claim, not least because heterodox economists see themselves as being in opposition to neoclassical economics. It may even appear reckless, given that heterodoxy is sometimes characterized by its critics as amounting to little more than a general opposition to neoclassical economics.[1] But on closer inspection, Lawson's claim deserves more careful attention. An important part of its substance is that heterodox economists' widespread use of mathematics in economic theory is contradictory to their (implicit) open-systems ontology (Lawson, 2013, pp.955-8).[2] The purpose of this chapter is to address this criticism directly, and suggest that it need not be correct: there need be no contradiction between the use of mathematics and adherence to the ontological postulate that the economy is an open system.

The remainder of the chapter is organized as follows. Section 2 briefly reviews Lawson's recent assessment of neoclassical economics and criticisms of heterodox economics. Section 3 describes an open systems – *ceteris paribus* (OSCP) approach to mathematical modeling that addresses these criticisms. Section 4 concludes.

2 What is this "school" called neoclassical economics?

2.1 Lawson on neoclassical economics: are heterodox economists neoclassical?

According Lawson (2013, pp.947-53), the term "neoclassical" has lost touch with its original meaning, does not reflect continuity with Classical economics, and is used inconsistently even by those who seek to give it a coherent meaning. Ultimately, Lawson argues that it would be best to abandon use of the term altogether. As a second-best alternative to this strategy, he suggests that a better and more coherent account of the term be furnished – a task to which he subsequently applies himself.

The motivation for this project is the claim that the loose and contested use of the term "neoclassical" that is currently prevalent hinders critique and reform of orthodox or mainstream economics, a project that can be successfully characterized without recourse to the term neoclassical. This is because the dominant characteristic of mainstream economics is mathematical modeling. For Lawson (2013, pp.953-55), the identification of this dominant characteristic points immediately to what is wrong with the mainstream project that demands critique and reform: it is a project that is at odds with the intrinsic nature of its object of analysis. Hence mathematical modeling is "deductivist", postulating "event regularities" characteristic of closed systems, whereas social systems are (in general) open. It follows that "the sorts of conditions under

[1] Even proponents of heterodox economics are wont to identify opposition to neoclassical economics as one of heterodoxy's key unifying themes. To take the example of Post-Keynesian economics, see the various references cited by Lawson (1994, p.503).

[2] On the implicit acceptance of openness in heterodox economics, see Lawson (2006).

which the modeling methods economists have employed would be useful are found to be rather uncommon, and indeed unlikely, occurrences in the social realm. Alternatively put, the ontological presuppositions of the heavy emphasis on mathematical modeling do not match the nature of the 'stuff' of the social realm" (Lawson, 2013, p.953).[3]

So what does any of this have to do with heterodox economics? In the first instance, Lawson (2013, pp.955-58) notes that while heterodox economists frequently criticize the mainstream's insistence on mathematical modeling, this criticism stems only from a desire for pluralism in the methods of economic inquiry. Heterodox economists seldom identify mathematical modeling as the quintessence of the mainstream project and seldom object outright to mathematical modeling *per se*. This, Lawson argues, creates something of a tension. On one hand, heterodox economists do not unequivocally reject mathematical modeling as a tool for the development of social science. On the other, they frequently (if often only implicitly) identify with the open-systems ontology that is incompatible with the deductivism of mathematical modeling. For example, Post-Keynesian emphasis on fundamental uncertainty (implicitly) recognizes the openness of the social realm (Lawson, 2013, pp.956-7).

In his subsequent ruminations on the meaning of the term neoclassical, Lawson (2013, pp.958-74) identifies this same tension – "a tension of ontological perspective and method (or the latter's ontological presuppositions)" (Lawson, 2013, p.958) – with Veblen's original characterization of neoclassical economics. He goes on to identify Veblen's usage as "the most appropriate, and a coherent, use of the category". The result of all this is straightforward: for Lawson, many self-described heterodox economists are properly described as modern-day neoclassicists. As Lawson himself puts it:

> So is it really the case that I am suggesting that all mathematical modellers in modern economics who at some level appear to subscribe to the causal-processual [open-systems ontology] world view, including those who self-identify as heterodox, are appropriately characterised as (modern-day) neoclassical economists? ... I certainly think this is the most coherent rendering of neoclassical economics (Lawson, 2013, p.975).

2.2 An initial (heterodox) response

As should be clear from the above, Lawson's Veblenian interpretation of the term neoclassical provides a basis for both: a) furnishing a coherent interpretation of the term that, by virtue of its coherence, makes

[3]For extensive elaboration on this theme, see Lawson (1997, 2003).

the term useful once again in economic discourse; and b) identifying a particular swathe of economists – a swathe that includes many who would self-identify as heterodox – as neoclassical economists.

An initial (heterodox) response to all this might be to respond dismissively. For several decades now, Lawson has attempted to draw the attention of heterodox economists to issues that link ontology and methodology and that in so doing, call into question the methodology of heterodox economics – at least as it is practiced in some quarters – given its (apparent) ontological presuppositions. What better way to call attention to this project than to label heterodox economists neoclassical, associating them at a stroke with the *bête noire* of their own project! But make no mistake: Lawson's is no idle rhetorical strategy in a meaningless war of words, and should not be treated as such. He raises real issues of substance that demand to be engaged.

Looking beyond his preferred use of the term neoclassical, the key issue on which Lawson seeks to focus is mathematical modeling and its (in)appropriate use in the articulation of social theory. Rejections of mathematical modeling are not new, of course. At the same time, there exist many practical defenses of the use of mathematics that have been advanced in response to rejections of its use. In general, these express the view that while some economists have so elevated the importance of mathematical modeling that it has become an end itself, once it is recognized that mathematics is merely a means to an end – a tool for expressing ideas about how the economy functions – appropriate use of mathematical modeling can be retained as part of the economic theorist's toolkit. In short, mathematics is a "good servant but a bad master". One need not look to the mainstream project for this sort of defense: such sentiments are alive and well among heterodox economists. Consider, for example, the following from Geoff Harcourt:

> First, the vexed question of mathematics. This is a red herring. My own stance was influenced by Keynes. He argued that in a subject like economics there is a spectrum of appropriate languages, running from intuition and poetry through lawyer-like arguments to formal logic and mathematics. All have a role, depending upon the issue (or the aspects of an issue) being discussed. Mathematics is a good servant but a bad master, that is to say, always pose the economics of an issue first, then see whether some form of mathematics may be of use in solving the problems thrown up. This approach also has the blessing of von Neumann, Michal Kalecki and Josef Steindl, a worthy Trinity if ever there was one. (Harcourt, 2003, p.70)

Although her comments are ostensibly more critical of mathematical modeling (since her purpose is to critique the "hegemony of formalists" and to advocate for pluralism in economic methodology),[4] Victoria

[4] When referring to the hegemony of formalists, Chick treats "formalism" or "formal modeling" as synonymous with math-

Chick expresses sentiments that are essentially similar to those of Harcourt when she writes:

> In my view, economics is a subject so complex and interwoven that the achievement of cogent knowledge by any single method is impossible; therefore there is scope and need for a variety of approaches. Formal methods cannot claim to be the only valid approach, at least in their present forms. Formal techniques are powerful tools, but they can also be dangerous; the problem is to identify applications where they can be used safely. (Chick, 1998, p.1859)

In other words – and to quote the title of Chick's paper – the use of mathematical modeling in economics boils down to a question of "knowing one's place".[5]

Lawson's rejection of mathematical modeling is by no means absolute. Indeed, on the face of it, his concerns appear quite compatible with the sentiments of Harcourt and Chick outlined above. Hence he writes:

> I hope by now the highly conditional nature of my criticism is apparent. It is not, and never has been, my intention to oppose the use of formalistic methods in themselves. My primary opposition, rather, is to the manner in which they are everywhere imposed, to the insistence on their being almost universally wielded, irrespective of, and prior to, consideration of explanatory relevance, and in the face of repeated failures (Lawson, 2003, p.xix)

Lawson's objections to mathematical modeling are, however, more pointed than mere concern with the possibility that it has become a "bad master". The essence of his argument concerns ontology, and the (in)consistency of mathematical modeling with the (implicit) conception of the economy as an open system that many heterodox economists appear to entertain (Lawson, 2006). The premise in what follows is that any truly compelling defense of mathematical modeling must engage this alleged inconsistency and in so doing, show that mathematical modeling is not (or at least *need not be*) inconsistent with open-systems ontology.

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ematical modeling. In general, however, she argues that mathematics is only one way of expressing arguments "formally".

[5]It should be noted that according to Chick's analysis there are limitations to the use of mathematical modeling because of the open and organic nature of economic reality. Unlike many contributions to the "good servant, bad master" doctrine, Chick is therefore sensitive to the ontological issues identified below with Lawson's critique of mathematical modeling. Ultimately, her analysis implies that mathematics can only usefully be used to illuminate *some parts* of the economy, and is never a sufficient tool for economic analysis. Although it is not the purpose of this chapter to argue that mathematical modeling is a sufficient tool for economic analysis, it can nevertheless be thought of as extending Chick's argument by suggesting that even open systems can (although need not be) represented by mathematical models, if the latter conform to the OSCP methodology described below.

3 An open-systems, *ceteris paribus* (OSCP) approach to mathematical modeling[6]

3.1 Methodology and ontology

The crux of Lawson's objection to mathematical modeling is that mathematical models are "deductivist", meaning that in such models, causality is understood in terms of constant conjunctions of events or "event regularities" of the form "whenever event x, then event y". Consider, for example, a simple aggregate consumption function of the form:

$$C = cY \tag{1}$$

where C denotes aggregate consumption, Y is aggregate income, and c is the average (and marginal) propensity to spend. In equation (1), whenever there is an increase in aggregate income, then there is an increase in aggregate consumption. In other words, causality is precisely of the "whenever event x, then event y" or event regularity form. But systematic observation of constant event conjunctions is properly understood as a feature of systems characterized by both extrinsic closure (as a result of which effects always have the same causes) and intrinsic closure (as a result of which causes always have the same effects). The problem is that if social reality is structured but *open*, event regularities will be rare in social systems. This means that mathematical models, premised on closed systems in which event regularities are common, must be unsuitable vehicles for expressing economic theory.

Mathematical models need not fall prey to this problem, however. What Setterfield (2003, 2007) calls the open systems – *ceteris paribus* (OSCP) approach to mathematical modeling is designed to avoid it altogether by explicitly confronting ontological concerns with the openness of social systems.

As its name suggests, the OSCP approach is based on explicit recognition that one of the essential properties of social systems is that they are open. Mathematical models constructed in accordance with the OSCP approach should themselves, therefore, either be open, or else embody only *conditional closures*. Conditional closures are introduced into a model by describing as constant variables and/or structural relations that are understood to be transmutable and are therefore known to be capable of change over time. The artificial or temporary nature of the resulting closure is then explicitly acknowledged – a process akin to what Kregel (1976) describes as "locking up without ignoring" certain dynamic features of a system in the

[6] The analysis in this and the following section borrows extensively from Setterfield (2007) and Setterfield (2014).

methodology of Keynes and Post-Keynesian economics.[7] Note that it is the use of conditional closures that introduces the *ceteris paribus* limiter into the OSCP approach. Hence in this context, the term *ceteris paribus* draws attention to the fact that a model is a partial representation of reality, not simply because it abstracts from some features of reality (all models do this by definition), but rather in a strictly dynamic sense. Specifically, within the temporal frame of reference of the model itself, some things that are transmutable and known to be capable of change over time (including things that are understood to be subject to novel change and for which there does not exist, in principle, any foreclosed rule (equation) of inter-temporal motion) are held constant.[8] As will become clear, there are two different types of conditional closure and it is as a result of this that such closures may be either artificial or temporary, as suggested above.

The type of functional relations used to articulate formal models of the OSCP genus specify transmutable, conditional relations of the form:

$$y = f_t(\mathbf{x}_t) \tag{2}$$

where y is the dependent variable, $\mathbf{x}$ denotes a vector of independent variables, and the precise meaning of the t-subscripts will be discussed in due course. Detailed examination of equation (2) reveals why Lawson's claim that mathematical models are deductivist is true only some of the time, and problematic only some of the time that it is true. First, the time subscripts in equation (2) denote that the precise form of the function f together with the contents of the vector $\mathbf{x}$ (not just the magnitudes of the scalar quantities of which it is comprised) are time-dependent. Causes need not always have the same effects or effects the same causes – i.e. the system lacks both intrinsic and extrinsic closure. But this does not mean that there are simply "missing equations". Rather, f and $\mathbf{x}$ are understood to be transmutable in novel ways. Their change over time cannot be "endogenized" in the conventional manner (i.e. reduced to foreclosed explanation in terms of given and immutable data), thus re-imposing system closure as the result of a successful search for Lucasian "deep parameters" that are invariant with respect to changes introduced into the system from without (such as a new tax, or a new strategy to match competitors' prices) by parties public or private.[9]

[7] Conditional closures might also be referred to as provisional closures in the nomenclature of Chick and Caserta (1997).

[8] The astute reader will note the generalization of the Lucas critique (Lucas, 1976), resulting from the hypothesized absence of "deep parameters", that is implicit in this last statement (see also Lawson (1995)). We will return to this theme immediately below.

[9] See Lawson (1995) on the generalization of the Lucas critique implicit in this interpretation of equation (2), and in particular Lawson (1995, pp.266-71) for detailed criticisms of the mainstream project of "solving" the problems raised by the Lucas critique by means of extending and re-fashioning models in the search for eventual system closure.

Note that, for Lucas (1976), the problems posed by the Lucas critique are specific to public policy interventions. As the above characterization of deep parameters suggests, however, once social systems are conceived as open and the substance of the Lucas critique is thereby generalized, the problems that the critique poses are found to confront all decision makers whose behavior is conditioned upon a characterization or "model" of the social system in which they wish to intervene. See also

Instead, by virtue of the innate openness of social systems, deep parameters are hypothesized not to exist, and the functional relation in equation (2) remains open. Moreover, because equation (2) is open, it will not (in general) generate event regularities and therefore cannot be considered a form of deductivism. Any conjunction of events expressed by the model in one period will likely cease to obtain in the next and does not, therefore, constitute an enduring event regularity. In other words, the very purpose of an expression such as equation (2), based on the OSCP approach to mathematical modeling, is to explicitly capture and emphasize the fact that any particular conjunction of events today should not be expected to re-materialize in the future, because of the lack of intrinsic and/or extrinsic closure characteristic of the data generating process from which observed outcomes emanate.

As noted earlier, the OSCP approach does allow for the introduction of conditional closure into mathematical models, as a result of which certain dated variables that are known to be transmutable and capable of change over time (such as the precise form of f or the composition of $\mathbf{x}$ in equation (2)) are held constant. Conditional closures can be introduced in two ways, both of which entail a process of "locking up without ignoring" the openness that is believed to characterize social systems (Setterfield, 2003, pp. 76-78). Hence, "pure" locking up without ignoring involves introducing closure as an analytical device, in order to illuminate more clearly some particular principle or feature of an economic system.[10] Although properly conceived as convenient fictions, the resulting closures can serve important pedagogic purposes – indeed, their introduction is conditional on the fact that they do – even when they involve locking up without ignoring an essential feature of a system's dynamics. This is exemplified by Keynes's assumption of a constant state of long run expectations in order to demonstrate the principle of effective demand (Kregel, 1976). By making this assumption, Keynes ruled out any effect of disappointed short-term expectations on the state of long-run expectations – a potential source of indeterminacy in the principle of effective demand. The resulting system is conditionally closed by the assumption just noted, but nevertheless serves an important purpose: it suffices to demonstrate the relative autonomy of aggregate demand conditions in the determination of output and employment. It is interesting in the current context to note Kregel's conclusion that "it would the appear to be a disservice to both Keynes's methodology and that of the post-Keynesian writers to accuse them of some other parentage or ... to bracket their writings with orthodox approaches .. Their basic methodology is distinctly different" (Kregel, 1976, pp.222-3). Apparently, not all closed systems are created equal.[11]

Lawson (1995, p.271).

[10] A mathematical model involving "pure" locking up without ignoring may be likened to what Hodgson (2004) identifies as a "formal heuristic", the purposes of which are to "identify possible causal mechanisms that form part of a more complex and inevitably open system" and thus "to establish a plausible segment of a causal story, without necessarily giving an adequate or complete explanation of the phenomena to which they relate" (Hodgson, 2004, p.7).

[11] Of course, this example also illustrates a potential pitfall of models based on OSCP methodology: they can all too easily be

Conditional closure can also be introduced by means of "empirically grounded" locking up without ignoring. This is based on the observation of actually existing, relatively enduring institutions (norms, conventions, rules, etc) within the system that is being modeled. These institutions can be expected to arise in response to the very openness of social systems which, by rendering the future fundamentally uncertain, and hence future-oriented (consequentialist) decision making difficult to practice, can have a debilitating effect on ends-oriented behavior.[12] Institutionalized behavior, which involves a deliberate and reasoned abandonment of consequentialism in favor of proceduralism, provides a practical escape from this dilemma. And by routinizing behavior, institutions lend greater regularity to the flux of events than would otherwise be observed in the potentially kaleidic environment of an open system – at least, as long as they endure.[13] In this case, then, the validity of the closure introduced into a model is conditional on the purposive reproduction over time by human agents of an actually existing institution within the system that is being modeled, it being understood that one of the properties of institutions is to create greater regularity in actions and events than would otherwise be observed in their absence.[14] To summarize, the argument is essentially that: (a) the logic of social theory consistent with an open systems ontology suggests the capacity for episodes of conditional closure over restricted spatio-temporal regions, as individuals create and maintain institutions in response to fundamental uncertainty; and (b) these restricted spatio-temporal regions are non-trivial – on the contrary, their identification and study is an important and useful part of social science, and can inform the construction of ontologically-sensitive mathematical models consistent with the OSCP approach.

Two final points remain to be made about empirically grounded conditional closures. First, just as such closures will apply only to restricted spatio-temporal regions, so, too, will any event conjunctions to which they give rise. Because the underlying system is open and its very structure is ultimately transmutable in novel ways, it will display no propensity to generate *constant* conjunctions of events. These observations draw attention to the fact that a conditionally closed system is fundamentally non-atomistic, even as it may temporarily appear to display the properties of an atomistic system.

Second, when they are empirically grounded, conditional closures are not just a pragmatic modeling

misinterpreted. Hence, witness the countless examples of "hydraulic" Keynesianism that lack fidelity to Keynes's methodology (at least as it is identified by Kregel (1976)). See also Louçá (2001) on the correspondence between Frisch and Schumpeter regarding Frisch's model of the cycle for a telling account of how deductivism can both colonize and misrepresent the economic theories it claims to be articulating.

[12] The frustration of consequentialist decision rules (such as the comparison of marginal cost and expected marginal benefit) by fundamental uncertainty might give rise to anxiety. Alternatively, the seemingly limitless possibilities of an uncertain future might give rise to anomie. Either of these conditions can be thought of as debilitating in the sense that they thwart action.

[13] Institutions are transmutable in novel ways and the expectation must be that this transmutability will eventually assert itself.

[14] See also Crotty's discussion of "conditional stability" in macroeconomic systems for a similar account of the role of institutions in both actual economic systems and in macroeconomic models (Crotty, 1994).

strategy. Instead, a mathematical model based on empirically grounded conditional closures can claim fidelity to the social material it purports to represent. Indeed, the nested or hierarchical "closure within an open system" characteristic of such a model seems perfectly congruent with Lawson's own preferred "agency/structure interaction" view of society. Hence as Davis (2015) argues:

> while indeed it is a property of social reality that it is processual and highly transient, since this is what seeing the agency/structure pair as interaction requires, it is also ... a property of social reality that it is recurringly stable and temporarily unchanging. That is, when we adopt an agency/structure interaction view, social reality has both the property of change and the property of stability ... Put in terms of Lawson's agency/structure interaction view, human action presupposes social structures, so social structures must be stable enough to provide a basis for human action. Yet human action also transforms social structures, demonstrating their changing character. That is ... there is not only change *but importantly also stability within a process of change*. (Davis, 2015, p.7; emphasis added)

As Davis goes on to note:

> Thus it is not accurate to simply say that social reality is processual and highly transient, as this is an incomplete characterization of the properties of social reality ... the emphasis in "What is this 'school' called neoclassical economics?" is too strong on the side of social reality seen as changing and too weak on the side of social reality seen as in some manner unchanging. (Davis, 2015, p.7)

On this view, from both the OSCP perspective advanced in this chapter *and* on the basis of Lawson's own agency/structure interaction view of social reality, the fault that Lawson (2013) finds with heterodox mathematical modeling is, in general, incorrect, by virtue of its *getting the ontology wrong*: it puts too much emphasis on openness and change in social systems, and not enough on stability and inertia rooted in actually-existing conditional closures.[15]

Whether pure or empirically grounded, the process of locking up without ignoring is ontologically sensitive to the innate openness of social systems, and can result in conditional closures that have some validity – albeit of a spatio-temporally or analytically limited nature – in the analysis of what are ultimately understood to be open systems. Hence mathematical models generated by the OSCP approach to formalism that display conditional closures by virtue of proper application of the process of locking up without ignoring must also

[15] I am grateful to John Davis for drawing this last point to my attention.

share the same validity in the analysis of social systems. It follows that even when mathematical models do generate event regularities and thus seemingly resemble deductivist laws, this is not always a problem. To be more specific, mathematical models that describe universal, immutable event regularities *are* problematic, but those that appear deductivist only by virtue of the proper introduction of conditional closures into expressions such as equation (2) are not.[16]

3.2 An example

Examples of (implicit) appeal to OSCP methodology in economic theory can already be found in existing literature. Hence, elements of the OSCP approach are implicit in the mathematical characterizations of hysteresis due to Katzner (1998) and Setterfield (1998), the contrast between models of economic dynamics consistent with either logical or historical time in Harris (2005), and in the model of cycles due to Setterfield (2000). But the OSCP methodology outlined in the previous sub-section can be made more concrete by detailed discussion of an example of its explicit application. The example developed below is that of the dynamic credit supply curve developed by Setterfield (2014), designed to reconcile the horizontalist and structuralist positions regarding the shape of credit supply curve in endogenous money theory (on which see Lavoie (2007) and Dow (2007), respectively).

We begin by writing:

$$r_t = (1 + \theta_t)\delta_t \tag{3}$$

Equation (3) relates the value of the commercial interest rate (r) to the value of the discount rate (δ) and commercial banks' mark up (θ). The equation explicitly purports to describe the behavior of the commercial rate over time, as a result of inter-temporal variations in the discount rate and/or the mark up and has a basic structure that is immediately recognizable as being akin to that of equation (2).

Let θ_0 and δ_0 denote the values of θ and δ, respectively, in some initial instant. We now write:

$$\theta_t = f_t(Y_t) \tag{4}$$

$$\delta_t = g_t(Y_t) \tag{5}$$

where $f_t', g_t' \geq 0$. These expressions are once again compatible with the structure of equation (2). Equa-

[16] See also Chick and Dow (2001, pp.711-14) for a similar conclusion.

tions (4) and (5) express the possibility that θ and/or δ will vary over time with nominal income (Y), the assumption being that increases/decreases in Y are accompanied by increases/decreases in the demand for credit arising from the finance motive.[17] Note that equations (4) and (5) express only the *possibility* that θ and/or δ will vary with Y, because the first derivatives of these equations may be either greater than or equal to zero. More importantly, f_t and g_t (and hence their derivatives) are time varying, so that we can have $f_t', g_t' \neq 0$ even if $f_{t-1}', g_{t-1}' = 0$ (or vice versa). Moreover, note that the precise evolution of f_t and g_t (and hence their derivatives) remains deliberately unspecified. This is because f_t and g_t are understood to be transmutable in novel ways – there are no "missing equations" that can be introduced to close the system in equations (4) and (5) so as to give rise to a determinate relationship between r_t and Y_t expressed in terms of Lucasian deep parameters. Instead, the system remains intrinsically open, and the relationship between r_t and Y_t will not be characterized by event regularities since the causal event $\dot{Y}_t$ will not always have the same effect (as measured by $\dot{r}_t$). In other words, it is impossible to make "whenever x then y" statements of the form "whenever nominal income expands, commercial interest rates rise" (structuralism) or "whenever nominal income expands, commercial interest rates remain the same" (horizontalism).

The point established by this analysis is that Post-Keynesians should not attempt to substantiate either horizontalist or structuralist arguments as a matter of a priori logic, and thus seek to establish that the dynamic credit supply schedule in (3) is either horizontal or upward sloping *in principle*. To do so would involve insisting that "missing equations" can be introduced into the analysis that render the resulting relationship between the commercial interest rate and nominal income closed – i.e., equations (3) – (5) would express an event regularity of the form "whenever nominal income increases, the commercial interest rate rises" or, alternatively, "whenever nominal income increases, the commercial interest rate stays the same". This would permit the drawing of a dynamic credit supply schedule that is either upward sloping or horizontal. But in the process, it would rule out the possibility that there is, in fact, no foreclosed relationship between nominal income and the commercial interest rate, and that this relationship is, instead, *open*. And since it is open systems that are congruent with the Post-Keynesian conception of historical time while closed systems belong in the domain of logical time (see, for example, Lang and Setterfield (2007)), this would be tantamount to providing a logical time account of an economic process unfolding in historical time. As such – and per Lawson – it would violate one of the first principles of Post-Keynesian economics:

[17]As will become clear below, $f_t' \geq 0$ expresses the possibility that (for example) variations in loan demand are accompanied by changes in lenders' risk; $g_t' \geq 0$ expresses the possibility that the central bank will react (by changing the discount rate) to nominal expansion/contraction of the economy. In other words, there are well-specified behavioral foundations in monetary macroeconomics for both $f_t', g_t' > 0$ and $f_t', g_t' = 0$: the mathematical structure of equations (4) and (5) is representative of plausible monetary behavior that can be extracted from the structuralism versus horizontalism debate in endogenous money theory. See (Setterfield, 2014).

that economic processes unfold in historical time and that economic analysis must be congruent with this fact.

Consider now how the dynamic credit supply curve does, in fact, work. On the basis of equations (4) and (5), we can write:

$$\dot{\theta}_t = f_t' \dot{Y}_t \tag{6}$$

$$\dot{\delta}_t = g_t' \dot{Y}_t \tag{7}$$

Combining this information with the initial conditions θ_0 and δ_0 and equation (3), it follows that over any time horizon $t = 0, ..., n$ that is longer than an "instant",[18] the dynamic credit supply schedule is given by:

$$r_t = (1 + \theta_0 + \int_{t=0}^{n} f_t' \dot{Y}_t \, \mathrm{d}t + \int_{t=0}^{n} g_t' \dot{Y}_t \, \mathrm{d}t) \tag{8}$$

Note that if $f_t' = g_t' = 0$ for all t, then we will observe $r_t = r_{t-1}$ for all t and the dynamic credit supply schedule will be horizontal. But if $f_t' \neq 0$ and/or $g_t' \neq 0$ for some t, then we will observe $r_t > r_{t-1}$ for some t and the dynamic credit supply schedule will be an upward-sloping step function. In short, the dynamic credit supply schedule in equation (8) encompasses both horizontalist and structuralist positions regarding the shape of the credit supply schedule, and does so by embracing what is understood to be the intrinsic openness of the monetary relations from which observed behavior of the nominal interest rate is derived.

4 Conclusions

According to Lawson (2013), the best available definition of a neoclassical economist is one who fails to recognize an unresolved tension between their methodology and their ontological presuppositions. This means that many economists who self-identify as heterodox are, in fact, modern day neoclassicists, because they employ mathematical modeling techniques while (implicitly) entertaining an open-systems ontology. The unresolved tension to which this combination gives rise emanates from the fact that mathematical modeling is deductivist: it presupposes system closure and is therefore incompatible with an open-systems ontology.

[18] During an "instant", institutional features of the banking system make (4) and (5) conditionally closed. Specifically, we observe $f_t' = g_t' = 0$, for $t = 0, ..., k$ (this last expression defining the interval of the instant, during which both the mark-up and the discount rate are always constant). We therefore have $r_t = (1 + \theta_0)\delta_0$ from (3), where θ_0 and δ_0 are historically-given data.

The arguments advanced in this chapter involve several key points of departure from Lawson's position. Each of these emanates from an open systems – *ceteris paribus* (OSCP) approach to mathematical modeling, that promises to contribute to the Lawsonian goals of better economic theory and explanatory success by embracing the Lawsonian notion that proper economic method and theory must be derived from (and consistent with) an explicit social ontology. The first point of departure concerns Lawson's identification of mathematical modeling with deductivism (Lawson, 2013, pp.950, 953). For Lawson, "mathematical methods and techniques of the sort employed by economists (functions, calculus and so forth) presuppose regularities at the level of events" (Lawson, 2013, p.953). The OSCP approach to mathematical modeling denies this, claiming instead that mathematical expressions of causal relations *need not* involve closure and event regularities.

The second point of departure is Lawson's (implicit) notion that closure, because it represents an unrealistic portrayal of the intrinsic nature of social material, is always and everywhere undesirable in the formulation of economic theory. The position taken in this chapter is that some invocation of closure may serve a limited but useful pedagogical function – akin to the method adopted by Keynes in the *General Theory* for outlining the principle of effective demand (Kregel, 1976), and the use of provisional or conditional equilibrium as organizing constructs for theory development advocated by Chick and Caserta (1997) and Setterfield (1997).

The final point of departure is Lawson's conception of closure in social systems as being uncommon to the point of being negligible. The OSCP approach to mathematical modeling posits, instead, that closures are socially constructed (through institutions created in response to the anxiety/anomie that the indeterminacy of an open social reality creates) and that although transient, may be sufficiently durable to be worth taking into account in social theory. Lawson acknowledges this approach when writing "where within heterodoxy, a continuing faith in, and/or resources allocated to, exercises in mathematical modeling are not accounted for by an inattention to ontological preconceptions of methods, the explanation is seemingly that the individuals in question entertain hopes of identifying certain contexts in which local closures (facilitating the appropriate use of mathematical methods) do, temporarily, obtain" (Lawson, 2013, p.957). But as the general tenor of this quotation suggests, he does not set much store in the approach. The commonality and durability of local closures is not something that can be resolved as a matter of logic and is worthy of empirical investigation as an outgrowth of the methodological debate over the use of mathematical modeling in economics.

To summarize, for Lawson:

> a good deal of sustained heterodox research is couched in conceptual frameworks consistent with

.. [a] causal-processual ontological conception ... All too often, however, this goes hand in hand with a lack of realisation that methods of mathematical modeling require formulations that are in severe tension with this ontology. (Lawson, 2013, p.957).

The position advanced in this chapter, meanwhile, is that mathematical modeling does not *require* such formulations, and where the noted tension does arise, explicit *acknowledgment* of the tension is as if not more important than the tension itself. In other words, the argument that mathematical modeling must always describe closed systems that generate event regularities is:

(a) true only some of the time, depending on the approach to [mathematical modeling] that advises the author ...; and
(b) problematic only some of the time that it is true, again depending on the approach to [mathematical modeling] that advises the author (Setterfield, 2007, p.204).

It follows that as long as heterodox economists are explicitly mindful of ontological concerns when constructing mathematical models, and engage in mathematical modeling accordingly (under the auspices of the OSCP approach), their use of mathematics in the development of economic theory does not mean that they necessarily fall victim to a mismatch between ontology and methodology. The Veblenesque charge of "neoclassicism" is thereby avoided, revealing that Lawson's critique of heterodox practice, while true in some cases, need not be in all.

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