A Process Philosophy Perspective on an On-line, Macroeconomic Teaching and Learning Project

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We discuss the findings of a Project conducted at the University of Newcastle over 2007-8 developing a new student-centred and problem-based learning course in Intermediate Macroeconomics.

Introduction

The purpose of the paper is to discuss the findings of a Project that was funded by the Teaching and Learning Centre of the University of Newcastle over 2007-8, which had the aim of developing an interactive, on-line support environment for a new student-centred and problem-based learning course in Intermediate Macroeconomics.

Like the Project itself, this paper grounds itself in Alfred North Whitehead’s philosophy of organism. The rationale for this approach will now be reviewed. Whitehead wrote influential essays on the purposes and practices of education. In particular, his notion of “inert knowledge” has permeated the teaching and learning literature on “interactivity” in on-line environments. For him (Whitehead, 1968b: 171), passive learning was an anathema. In *The Aims of Education* he argues for an appropriate mix between theory and application:

This discussion rejects the doctrine that students should first learn passively, and then, having learned, should apply knowledge. It is a psychological error. In the process of learning there should be present, in some sense or other, a subordinate activity of application. In fact, the applications are part of knowledge. For the very meaning of things known is wrapped up in their relationship beyond themselves. Thus unapplied knowledge is knowledge short of its meaning (Whitehead, 1929).

Making mistakes, Whitehead observed, was a necessary part of the learning process for new advances in knowledge could only be made by “working within present experimental error”.

In addition, there are strong resonances between Whitehead’s distinction between visceral and visual modes of perception and Michael Polanyi’s distinction between tacit and codified forms of inference. This notable congruence, despite superficial differences, between Whitehead’s notion of visceral perception and Polanyi’s conception of tacit inference, would suggest that the latter’s philosophy could shine new light on the now
extensive literature on knowledge management, including dynamic capabilities theory (Teece et al., 1997), which applies the Polanyian concept of tacit inference to the analysis of economic phenomena as diverse as those of strategic alliances (Mowery et al., 1996), the management of R&D networks (Blanc & Sierra, 1999), and processes of collaborative learning and knowledge management within the multi-national enterprises (Zander, 1998; Zanfei, 2000).

Whitehead’s process philosophy grew out of his rarefied efforts to ground mathematics in formal logic. In the Western (and Arabian) philosophical tradition inherited from the Greeks—Heraclitus, Pythagoras, Anaximander, Parmenides and Plato—metaphysical deliberations on the nature and meaning of mathematics have an unparalleled importance. Inquiries into the nature of mathesis have continued to be pursued by contemporary thinkers, especially in regard to the philosophical implications of complexity theory and recent developments in Non-Euclidean and differential geometry. Concerns of this nature are also the focus of an influential body of literature on teaching engineering, computer science and quantitative aspects of the social sciences using system dynamics software and algorithmic “laboratories”.

However, Whitehead’s more focused philosophical discussions about the problem of induction and probabilistic inference, and his related notion of a ‘nested ontology’, influenced Keynes, when he was drafting _The General Theory_, in making a fundamental distinction between the nature of short-run and long-run expectations. This is a theme of crucial importance for modelling anticipative forms of social and economic behaviour.

For Whitehead, the notion of visceral perception is correlated specifically with the development of varying “degrees of rational belief” in the outcomes of probabilistic inference. Keynes’s use of Whitehead’s analysis of probabilistic inference have the potential to transform the way that macroeconomic modelling, policy development and evaluation are understood and represented. These considerations have implications for the interactive forms of pedagogy that Whitehead advocates.

Accordingly, this paper focuses on the pedagogical aspects of Whitehead’s philosophy. Section One reviews the objectives and elements of a Teaching and Learning Project. Section Two examines various aspects of Whitehead’s process philosophy from a largely pedagogical perspective. Section Three surveys some of the recent literature—both economic and non-economic—on the use of System Dynamics as a pedagogical tool. Section Four examines the implications of Whitehead’s thought for Keynesian Macroeconomics. All these aspects are brought together in Section Five, which examines their implications for Macroeconomic Modelling and Policy Evaluation. Concluding comments follow in Section Six.

1. The Objectives of the Project

The primary objectives of the Teaching and Learning Project described above are to: a) attract more ‘undecided’ students to choose an economics major; b) develop a more student centred approach to the teaching of macroeconomics; c) exploit blended learning
techniques; d) overcome what Whitehead has called “inert knowledge” through the exploitation of the potential for on-line interactivity; e) more widely disseminate the approach researchers at the University of Newcastle’s Centre of Full Employment and Equity have taken towards both macroeconomic analysis and the development and evaluation of policy interventions designed to achieve full employment with low inflation and high productivity.

These objectives are to be achieved through the development of a sophisticated on-line website featuring computer animated models, diagrams, linked theoretical content, associated web resources on macroeconomic themes, a related tasks and questions designed to promote various modes of active and interactive learning.

An important feature in the construction of this on-line teaching material will be the use of simple ‘exploding’ diagrams that can gradually be rendered more complex through gradual decomposition. For example, vertical transactions between the government and non-government sectors, which create or destroy net financial assets, will gradually be broken down into their component parts, followed by a further decomposition of horizontal transactions between banks, firms and households within the non-government sector.

A suite of diagrams are currently under development to support the structure of the proposed textbook. The first of these diagrams will detail vertical transactions between the consolidated government sector (combining Treasury and the Central Bank) and non-government sectors and, thus, the creation of net financial assets. Included will be material on the construction and inter-relationship between economy-wide balance-sheets, flow-of-funds accounts, and T-accounts. Crucially, analysis of the flow-of-funds accounts (see below) will reveal the importance of the distinction between vertical transactions and those that are internal to the consolidated government sector; the relationship between vertical transactions associated with budget surpluses and deficits and the creation or destruction of net financial assets; and the fact that horizontal transactions between banks, households and firms net out to zero. This difference between vertical and horizontal transactions is fundamental to an understanding of debt and asset accumulation in a monetary production economy. For example, a growth in private sector activity can compensate for contractionary fiscal policies (i.e. large budget surpluses), but only at the cost of ballooning and potentially unsustainable levels of private sector debt. This is because the non-government sector must be spending more than they save when the government sector is in surplus.

A second diagram will be linked to a simple spreadsheet (and ultimately a Simulink) expenditure model to convey the notion of effective demand in a closed economy (i.e. with no accounting at this stage for trade with the Rest-of-the-World); the relationship between income and expenditure; the components of expenditure (investment, consumption, and government spending); the fundamental accounting identities linking government spending and taxing (the budget surplus/deficit) with non-government spending and saving (the private sector surplus/deficit); and, the significance of the marginal propensity to save, and the marginal efficiency of capital. In a clear departure
from traditional text-book approaches, the analysis of circular flow will incorporate government transactions from the very beginning. The interactive spreadsheet model will be linked to graphical interfaces with interactive tabs that allow users to change parameters and policy settings, and be supported by explanatory “Flash” animations.

A third diagram will detail the relationship between components of expenditure and the demand for different financial assets (money, bonds and equity); the nature and significance of liquidity preference; the relationship between effective demand and aggregate supply; and, the determination of unemployment/underemployment outcomes in the labour market. Finally, a fourth diagram will demonstrate the implications of accounting for import, export and net income payments to and from the Rest-of-the-World sector.

Additional tests, activities, links to on-line resources, and quizzes will accompany each of the diagrams. To motivate initial interest, a preliminary Flash Quiz (accessible to registered students) will highlight common misconceptions about the nature of budget deficits and surpluses.

2. Educational Aspects of Whitehead’s Process Philosophy

2.1. The Bifurcation of Nature

For Critical Realists, the logic of scientific discovery operates under conditions of experimental closure, which enable underlying mechanisms to be described. This logic must work backwards from what is experienced to what is actualized—often in a contradictory and tendential manner—as the underlying mechanisms unfold. There are no doubt some superficial resonances between this notion of mechanism and the concept of process as articulated in Whitehead’s mature philosophy (1978: 32-33; 39-42). However, Whitehead’s (1978: 23) ‘principle of process’ states that, “how an actual entity becomes constitutes what an actual entity is.” In his efforts to overcome the bifurcation of nature into a causal, objective nature and a set of secondary, perceived qualities, Stengers (2005) argues that Whitehead refuses to engage in a critique that would question the claims of scientists that their objective laws describe nature independently of the perceiving mind. Instead, he held to the view that more was to be found in nature than could be observed at first sight. She suggests that, for Whitehead, our insights into nature are not reducible to transcendental, cultural, or linguistic constructions. We have to learn how to add to rather than subtract from scientific understandings. For Whitehead, a certain triviality marks the connection we establish between the universe as it is understood by modern physics, and as it matters to us as souls that require understanding. In philosophy, he acknowledges that the application of experimental method is a difficult operation weaving together disciplined human agency and captured material agency in the pursuit of a two-fold aim: on one hand it entails doing what the philosopher aims to achieve through the design of concepts and, on the other hand, ensuring that the aims of the philosopher are an adequate expression of the challenge that he or she has chosen to mount. Thus, what is constructed is less an “object of adequation” than a “matter of concern”.

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2.2. The Aims of Education: Inert Knowledge and Interactivity

Peterson (1999) has identified the broad affinities between the pedagogical philosophies of Whitehead, Gregory Bateson and Bill Readings. Each of these wide-ranging thinkers opposed the cult of the expert, over-specialization, and the “drift” towards power, authority and bureaucratic intervention within the universities of their day. Each of these thinkers also embraced what Petersen (1999: 28) chooses to call an ecological epistemology or philosophy of organism, for which the practice and thus the teaching science is less a question of proof and more a question probing, musing, mulling over and assaying: an approach to pedagogy that, of necessity, requires the active involvement of students.

Whitehead, for his part, distinguishes between first-hand knowledge and the second-hand knowledge arrived at through book learning. To attain first-hand knowledge, he contends, “heterogeneous thought” about nature must be cultivated. Such thought “bridges separate and distinct semantic fields” (Petersen, 1999: 31; citing Whitehead, 1955: 3): it is a thinking about nature “in conjunction with thinking either about thought or about sense awareness or about both…” In his public address on *Harvard: the future* Whitehead (1968: 159-160) proclaims that,

> Experience does not occur in the clothing of verbal phrases. It involves the clash of emotion, and unspoken revelations of the nature of things. Revelation is the primary characterization of the process of knowing. The traditional theory of education is to secure youth and its teachers from revelation. It is dangerous for youth, and confusing to teachers. It upsets the accepted coordinations of doctrine.

However, revelation is not something to be confined to the teaching of literature or the humanities for:

> Revelation is the enlargement of clarity. It is not a deduction, though it may issue from a deduction. The dictionaries are very weak on this point. […] The balance is difficult to hold. But it is well known that education as mere imposed order of “things known” is a failure. The initial stages of reading, writing, and arithmetic should be suffused with revelation.

In *The Aims of Education* Whitehead (1929) focuses in particular on how we can avoid “inert ideas”. He recommends that we, “Do not teach too many subjects,” and cautions that “What you teach, teach thoroughly.” Inertness obtains when small parts of a large number of subjects are passively absorbed as “disconnected ideas”, without illumination by “sparks of vitality”, and without being leavened by the “joy of discovery”. He deploys the term “understanding” in the sense applied in the French saying, “To understand all is to forgive all.” Above all, understanding should be useful, and should be directed at “the insistent present”, the holy ground which contains all there is.
Understanding comes through utilization, which in turn can come about through an appreciation of the importance of the idea. In this light, Whitehead (1929) suggests that proof is not essential but may be introduced later for completeness. Theoretical expositions should be short but thorough, and “not muddled up with the practice”. Proving should be kept separate from utilizing but what is utilized should be proved and what is proved should be utilized. He was an advocate of practical education arguing that,

An evil side of the Platonic culture has been its total neglect of technical education as an ingredient in the complete development of ideal human beings.

Whitehead’s maxim is to avoid small parts of a large number of subjects. Moreover, he warns that one thing to avoid is the conception of the mind as an “instrument” that requires “sharpening”. The mind is perpetually responsive and receptive, never passive, “you cannot postpone its life until you have sharpened it”! The apprehension of ideas is a patient process, with no “royal road” to understanding. The issue is less mistaking the wood for the trees than one of making the pupil see the wood by means of the trees. Whitehead (1929) saw the dangers in academic over-specialization complaining that,

Each science confines itself to a fragment of the evidence and weaves its theories in terms of notions suggested by that fragment. Such a procedure is necessary by reason of the limitations of human ability. But its dangers should always be kept in mind. For example, the increasing departmentalization of universities over the last hundred years, however necessary for administrative purposes, tends to trivialize the mentality of the teaching profession.

For him, there is only one subject matter in the modern curriculum, that being “Life in all its manifestations.”

I lay it down as an educational axiom that in teaching you will come to grief if you forget that your pupils have bodies.

The main target of Whitehead’s critique in The Art of Education are “inert ideas,” or notions “that are merely received into the mind without being utilized, or tested, or thrown into fresh combination”. Inertness results from the passive absorption of “disconnected ideas”, without illumination by “sparks of vitality”. For him,

Education, in every branch of study and in every lecture, is an art. It is essential to keep in mind, that science and poetry have the same root in human nature. Forgetfulness of this fact will ruin, and is ruining, out education system (Whitehead, 1929)
It is easy to understand why Whitehead’s notions of inertness have been taken up by the distance education community for whom the notion of ‘Interactivity’ Learning is goal directed (i.e. motivated by interest), failure driven (i.e. enhanced through processes of trial-and-error and mechanisms that reveal gaps in knowledge), case-based (situated in relation to real-world problems), and tied to processes of doing or learning through use and application (Schank et al, 1995: 633). Accordingly, learning systems must create engrossing environments, allow students to make mistakes, provide memorable case-based learning situations that allow access to expert opinion, and build rich and realistic simulated environments.

2.3 Visceral and Visual Modes of Perception

Whitehead introduces his fundamental distinction between visceral and visual feelings to question the Humean dogma that all percepts are in the mode of presentational immediacy and thus our construction of causal relations is illusory. For Hume notions of cause and effect were subjective projections imposed over constant conjunctions of events. More sophisticated philosophical versions of realism reject this argument. For Whitehead, presentational immediacy, which derives from visual feelings, is a process lifting into clear, distinct prominence and relevance the ‘extensive’ relations of the contemporary world. However, causal efficacy, which derives from visceral feelings, is a process occasioned by “extreme vagueness,” and a consciousness of the “settled world in the past as constituted by its feeling-tones, and efficacious by reason of these feeling-tones”. A mixed mode of Symbolic Reference obtains when visual and visceral feelings are combined. Unfortunately, an admixture of the two modes can give rise to error, which emerges when one mode is interpreted by the other. This is analogous to the synesthesia and confusion of senses resulting from a mixing of two species within the same perceptive mode.

In his overview of Process Philosophy’s theory of knowledge Latour (2005) argues that, for Whitehead, perception directs us, not to perceiving mind, but to point of view, locus, what is grasped by science. Drawing on the pragmatist notion of a multiverse as a universe freed from its premature unification, Whitehead contends that what scientific knowledge constructs is less an object of adequation than a “matter of concern”. Science must be interesting and risky, it must provide opportunities to differ, thus establishing good rather than bad generalizations, which in turn allow for a common world.

Latour (2005) instances the odour kits used in the perfume industry for training “noses” (i.e. those who can precisely distinguish between different kinds of scent to determine their constituents). While knowledge about different scents has evolved over a long period, influenced in part by the history of perfume making, the resulting taxonomies and classification schemes are more than a mere linguistic construction to the extent that they express of the way that different scents are created or engendered.

Whitehead’s distinction between visceral and visual feelings closely resonates with Michael Polanyi’s distinction between tacit and non-tacit forms of inference. Polanyi’s own work respects the dangers associated with trans-disciplinary research insofar as he is vehemently opposed to any Laplacian reductionism of the social sciences to the
psychological, the psychological to the biological, and the biological to the physical sciences. In opposition to this reductionist approach Polanyi develops a stratified ontology. As we move from the physico-chemical to the biological to the psychological and up to the social we navigate irreversible transitions that entail higher levels of ethical responsibility and meaning. Each of the preceding ontological layers determine the boundary conditions for the layers that succeed it. However, in ascending to the social domain vocabulary supports syntax, which in turn supports semantic processes, while sensory-motor capabilities support intelligence, which in turn supports processes of responsible choice.

Polanyi’s analysis of tacit inference conforms to this broader anti-Laplacian frame! For tacit inferences to be made a unified object must be isolated (via what Polanyi calls focal awareness) against a background (discerned through a form of subsidiary awareness). This positing is determined by a diffuse and almost subliminal perception. In addition it is an irreversible process, creating new qualities that are not explicitly present amongst the subsidiary elements. Polanyi cites, as a metaphorical example, the binocular perception of depth for which the whole is always greater than the parts and, when reversed, separate images would arise having lost any apprehension of distance or depth of field. While most obviously inherent in bodily activities such as playing pool or dancing, Polanyi argued that tacit inference is no less important in more ‘cerebral’ activities such as playing chess or even in pure mathematical analysis.

The political and policy implications of Polanyi’s conceptions extend to a forceful opposition to any top-down administrative control over scientific research. Tacit knowledge must be transmitted from master to apprentice through a process of learning-by-doing. Moreover, personal commitment is necessary for scientists to continue doggedly along a specific research trajectory even when evidence goes against them. Thus, financial support for scientific research should be determined by the scientific community itself, rather than by bureaucratic planners or via cost-benefit analysts. Also faults the Enlightenment project for wielding “the chisel of nihilism driven by the hammer of social conscience”.

Like Whitehead, most good teachers would acknowledge that the art of good teaching is to impart enthusiasm through the passion they can transmit to students: a passion that can only obtain as an expression of the vitality of their own convictions. Like Polanyi’s notion of tacit inference, Whitehead’s conception of visceral feeling relates to a mode of knowing that can only be successfully transferred on an individual basis either through personal experience or collectively via collaborative, face-to-face forms of “learning-by-watching” and “learning-by-doing”. Time and time again, the educationalist is confronted with the limitations and inadequacies of existing metrics and rubrics when it comes to measuring and offering guidance to these collective and individual learning processes, especially when it comes to distinguishing between “deep” or creative and “shallow” or routine forms of learning. The very novelty and uniqueness of the creative process belies the use of standards and normative measures. This raises the question of whether a systems-based approach might be more congruent with creativity in learning.
3. System Dynamics as a Pedagogical Tool

During preliminary research into the pedagogical material that might inform a project of this nature, a review of the literature on learning styles was undertaken—including work by Kolb, Myer-Briggs, and Felder. However, empirical confirmation seems to be lacking for many of these theoretical frameworks. While an extensive literature arose in the post-war period motivated by the insights of humanistic psychology into the nature of deep learning through motivation and engagement, much of this material is now seen to be dated and out of step with modern approaches informed by cognitive and evolutionary psychology. However, a body of research fostered by members of the systems dynamics community has been taken up and applied enthusiastically by economists who favour teaching methods that are based on imparting an intuitive grasp of system dynamics concepts within on-line environments.

Jay W. Forrester, Germeshausen Professor Emeritus and Senior Lecturer at the MIT Sloan School of Management, directed the System Dynamics Group until 1989. He was in charge of designing the first digital computer at MIT and from 1951 to 1956 headed the design and implementation of the SAGE air defence system in North America. In a recent paper surveying achievements in systems thinking he argues that system dynamics, systems thinking, and soft operations research (soft OR) all aspire to understanding and improvement of systems. Defining the equations of a model, simulating the model to understand dynamic behaviour, and then evaluating alternative policies accomplish this.

Forrester notes that model design, development and simulation can all be used for educational purposes. Moreover, he complains that case studies, generic approaches to systems thinking, and soft OR usually lack the discipline of explicit model creation and simulation and so rely on subjective use of unreliable intuition for evaluating the complex structures that emerge from the initial description of the real system. Nevertheless, with more emphasis on eliciting information from-real-world participants, he argues that these approaches should be able to contribute useful insights to system dynamics. Conversely, the model creation and simulation stages of system dynamics should contribute rigor and clarity to systems thinking and soft OR. Shaffer (2005) describes systems dynamics, reviews the literature of uses of systems concepts in distance education (DE), presents a preliminary model, and ends with a call to researchers to contribute to the building of a standard model of DE.

Wheat (2007) introduces system theoretic notions of positive and negative feedback loops and their interactions, to model the macro-economy as a governed system: accelerating process of accumulation (exhibiting positive feedback) are dampened through interactions between the aggregate price level and inventory holdings (via negative feedback). With a bit of tweaking, system dynamics models can also be constructed to represent the effects of imposing logistic resource constraints over growth (instanced by modelling of fishery populations), and the complex, non-linear dynamics associated with predator-prey relationships. The primary purpose of Wheat’s (2007) article, however, is to demonstrate the superiority of system dynamics modelling over the conventional analysis of shifting curves on graphs in the teaching of dynamic macroeconomic concepts.
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such as the “expectations augmented Phillips Curve” which represents the supposed trade-off between inflation and unemployment.

Carlson & Schodt (1995) contend that the ability to think like an economist should necessarily include creative skills: how to frame question, selection of tools to be applied, choice of pertinent data and information. In efforts to move beyond the lecture, problem set, and assignment format they favour a case study approach arguing that “[c]ases are narrative accounts of actual, or realistic, situations in which policy makers are confronted with the need to make a decision”. Students are provided with information but no analysis and must present a discussion on the case either individually or collectively. They examine outcomes for two case-based courses in Development Economics and International Monetary Economics.

Bartlett & King (1990) note that methods of teaching in economics have barely changed over last few decades although the requisite material to be covered has grown exponentially, while the time available for instruction is unchanged. Accordingly, the rush to cover material leaves little time for acquiring personal experience to ground material. However, they suggest that two factors—change in integrative rationale informed by educational theory; and, availability of low cost PCs—provide new opportunities for improvements in teaching practice. They suggest that computer labs allow students to work closely with their teachers, who have more time for one-on-one assistance.

Cardell, et al., (1996) examine the effects of demonstration projects in the use of economic laboratories that were conducted at both Denison and Washington State Universities. At Denison there was no control group, and a lecture-laboratory format was applied in the teaching of intermediate microeconomics, macroeconomics, econometrics, and in three advanced courses. They note that on-site supervision and feedback is important. They deploy regression comparisons of pre-Course and post-Course Test for understanding college economics (TUCE) results, noting that these scores increased from 4.3% for 1979 cohorts to 10.8% for 1989 cohort exposed to new technology. To assess the outcomes of the projects at Washington University, value-added model regressions were estimated using pre-Course and post-Course TUCE differences against a set of exogenous variables (including experimental group Y/N, gender, GPA score, previous exposure to economics course, if taking micro, percentage classes attended, mathematics and verbal SAT scores). However, no positive impact of laboratory use registered.

Some more positive evidence for the impact of on-line technology in economics education is provided in Sosin et al., (2004) who compare technology-enhanced introductory economics courses with their traditional counterparts. The authors present the results of (institutional) fixed effect panel regressions on survey data, which is decomposed into results for 67 sections of introductory economics, across 3986 students, in 15 institutions, with over 30 responsible instructors. They note that the technology variable is responsible for a statistically significant 2.3-2.5% difference in the change in pre- and post-Course scores. They note that the coefficient accounting for the use of power point is both negative and significant, while the use of emailing is negative and
significant in Macroeconomics and courseware is positively signed and significant. In Microeconomics teaching, however, emailing is positively signed and significant while courseware is not significant. The metric adopted is the TUCE measure. The authors note that TUCE has been the target of severe criticism because it is over 12 years old and does not measure higher cognitive functions. To improve robustness the researcher eliminate unreliable questions (8 out of 22 in macro) and one of the micro questions) using the Kuder-Richardson coefficient, which is derived from a factor analysis of questions. They also use initial class size as a variable to properly account for withdrawals and selection bias.

The representative literature reviewed above should serve to highlight the difficulties facing those who want to develop effective on-line teaching environments. Existing metrics and rubrics are inadequate to the task and evidence that could provide useful insights into issues of optimal design and evaluation is meagre and contradictory. In the economics discipline problems are compounded by the political divide between mainstream or orthodox theory and Classical, Evolutionary, Institutional and Post Keynesian theory.

Nevertheless, from a more generic, inter-disciplinary perspective the “System dynamics” view espoused by Wheat (2007) and Forrester (2006) emphasizes the importance of gaining an intuitive feel for the kind of “verbal” differential equations” that economists use to inform their discussions about growth process, issues of stability associated with perturbations away from equilibrium, or with the responsiveness of agents to changing price signals. Wheat (2007) suggests that intuition can be built up slowly through processes of model building and simulation, with students gradually gaining a familiarity with the output of positive and negative feedback loops, the nature of regulators that are constructed by combining both types of loop so that negative feedback constrains processes of forward feedback, and the role played by capacity constraints over resource-related activities. Eventually students can graduate to the simulation of non-linear systems associated with the economic analogues to biological models of predator-prey relationships.

This approach to the teaching of economic modelling can also introduce principles of learning design which recognize the need to start with simple models, whose components are then gradually ‘unbundled’ to yield systems of increasing complexity. Another advantage of system dynamics is the implicit imposition of rigorous stock-flow constraints over the modelling of economic processes. This is important for accurately capturing the effects of accumulating net financial assets (savings on the part of the non-government sector), and associated liabilities. This enables historical and simulated values for state variables to be correlated with T-accounts recording changes in sectoral stocks of assets and liabilities. Yet another benefit to be drawn from the use of a system dynamics approach is that model builders can manipulate the block diagrams used by engineers to visually represent complex dynamic relationships (see Andresen, 2006, for a recent Post Keynesian example of this block-diagrammatic approach to the simulation of monetary flows).
In the staged implementation of the project, the first interactive diagram that students confront is one representing the vertical transactions between a consolidated government (combining Treasury and Reserve Bank), and then a Consolidated Non-Government Sector (firms, households, and private banks). At this stage emphasis is placed on the role of vertical transactions and the fact that the government deficit creates net financial assets (NFAs) to meet the savings needs of those in the non-government sector. When, at a later stage, the non-government sector is decomposed into firms, banks, and households, the pedagogical focus shifts onto horizontal transactions within the non-government sector, demonstrating the role of the banking sector in driving the credit cycle. However, the accompanying analysis highlights the fact that horizontal transactions leverage off the net financial assets created by deficit spending and because all transactions within the sector net to zero in terms of the balance sheet. At a subsequent stage the “rest-of-the-world” sector is introduced highlighting the role of exchange rate determination and external debt. Here, the advantages of a floating exchange rate are emphasized.

In the Economics discipline alternative pedagogical approaches to those espoused by the System Dynamics community include the relatively straightforward use of Excel Spreadsheets (with the Solver add-in) to accomplish tasks as varied as the solution of optimal control problems (Weber, 19) and the simulation of stochastic real business cycle models (Hokari, et al). System dynamics modelling departs from these approaches insofar as it uses mathematical software to convert systems of differential or difference equations into polynomial matrix equations using Laplace and z-transform operators. The resulting matrix equation systems can also be manipulated through the use of efficient sparse matrix and quasi-concave optimization algorithms to accomplish such tasks as the derivation and solution of Ricatti equations, or to estimate the parameters of probability densities for stochastic perturbations to the model, under conditions of model uncertainty and observation error, including through the deployment of simple or extended Kalman filtering or more advanced techniques of robust and risk-sensitive control (see Juniper 2005).

In their explication of results derived from high dimensional, non-linear dynamic macroeconomic models, Chiarella et al (2006) apply a different though equally sophisticated set of analytical techniques that have been developed by members of the mathematical physics community for the qualitative analysis of Hopf bifurcations, (also see Asada, et al., 2006; and Franke, et al., 2006). Here, emphasis is placed on the sub-optimal control non-linear, far-from-equilibrium dynamics. However, this technically demanding material would only be suitable for post-graduate teaching and advanced research.

4. Whitehead and Keynes on Organicism

If accepted as a valid description of how human beings behave, Keynesian interpretations of long term economic decision-making under uncertainty have the potential to undermine most orthodox models of the macro economy, and may even throw into question the modelling approaches espoused by members of the non-linear dynamics discipline. 

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1 This Post Keynesian approach can advantageously be compared with its orthodox and profoundly contradictory counterpart as outlined in Thornton et al., (1991).
school of thought (Chiarella et al., 2006; Asada, et al., 2006; and Franke, et al., 2006). Although Keynes was strongly influenced in his philosophical views by G. E. Moore, Winslow (1989) argues that Whitehead exerted a greater influence over his interpretation of uncertainty and probabilistic inference.

Winslow (1989) argues that by the time he came to write the *General Theory*, Keynes had abandoned the atomistic ontology of the *Treatise on Probability* for Whitehead’s notion of organic interdependence. An atomistic ontology conceives of the essential characteristics of things as those of the individual and views relations that such entities have with other entities as purely external in nature. In contrast, an organicist ontology holds to the view that the essential properties of things are determined by internal relations they establish with other things.

The difficulty for those who espouse an organicist ontology is that everything can be construed to depend on everything else. To get around this problem Whitehead posited a nested ontology predicated on the notion that the structure of inter-relationships amongst entities was more stable at generic rather than specific levels of determination. From a temporal perspective, the shorter the distance into the future events had to be forecast, the greater would be the number of factors that could be treated as given. By the same token, the further into the future events had to be predicted, the larger would be the reduction in what could be treated as given, and the smaller the amount of knowledge that would be available for purposes of prediction. Winslow (1989) contends that this conception grounded the distinction Keynes (1936) made between short-run expectations (concerning remuneration from the exchange of goods and labour services) and long-run expectations (concerning the return on long-lived financial assets and capital).

However, Keynes was also persuaded by Freudian psychoanalysis, to which many members of the Bloomsbury Group were directly and indirectly exposed (Winslow, 1986, 2005, citing Freud, 1963; Forrester, 2003). As he distanced himself from G. E. Moore’s ethics of beauty, love and friendship, Keynes (X: 447; cited in Winslow, 2005) came to appreciate the irrationality of human existence, arguing that “civilization is a thin and precarious crust erected by the personality and will of a very few and only maintained by rules and conventions skilfully put across and guilefully preserved”. In his eyes, the ‘purposiveness’ of capitalism represented a psychopathological denial of mortality:

> For purposiveness means that we are more concerned with the remote future results of our actions than with their own quality or their immediate effects on the environment. The ‘purposive’ man is always trying to secure a spurious and delusive immortality for his acts by pushing his interest in them forward into time. He does not love his cat, but his cat’s kittens; nor, in truth, the kittens, but only the kittens’ kittens, and so on forward to the end of catdom. For him

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2 In contrast to Polanyi, whose main concern in developing a *layered* ontology was to oppose reductionism, Whitehead’s *nested* ontological structures had the aim of clarifying the supports for rational degrees of belief (i.e. probabilistic inference).
jam is not jam unless it is a case of jam tomorrow and never jam today. Thus, by pushing his jam forward into the future, he strives to secure for his act of boiling it an immortality (IX: 329).

Specifically, Keynes (IX; cited in Winslow, 2005) speaks of the reliance of capitalism on the money-making and money-loving instincts. This “love of money as a possession” and is a “somewhat disgusting morbidity, one of those semi-criminal, semi-pathological propensities which one hands over with a shudder to the specialists in mental disease. For psychoanalysis, the anal sadistic character type is associated with the traits of orderliness, parsimoniousness, obstinacy, and a sadistic love of power. In addition, Winslow (1986) points to evidence that Keynes adopted Ernest Jones’s (1948) distinction between more sublime (e.g. the “lure of compound interest) and more regressive (e.g. an unbridled lust for gold) forms of money love. Keynes suggested that in a financial crisis the latter would rapidly come to displace the former.

In the face of fundamental uncertainty Keynes argued that individuals within banks, households and firms would, in general, resort to “convention” rather than “caprice” because ritualized and seemingly rational forms of decision-making (that could not be justified in ontological terms) would serve to, “calm their disquietude” in the face of fundamental uncertainty. Keynes (X; cited in Winslow, 2005) never tired of poking fun at advocates of sophisticated decision-making techniques:

We used to regard the Christians as the enemy, because they appeared as representatives of tradition, convention, and hocus-pocus. In truth it was the Benthamite calculus, based on an overvaluation of the economic criterion, which was destroying the quality of the popular ideal.

In bringing together the two influences—the psychoanalysis of money love and process philosophy’s interpretation of uncertainty—Keynes sought to explain how variations in “money-love” would condition the three behavioural propensities: the preference for liquidity, the anticipated yield on capital, and the marginal propensity to save. Keynes (1936: Chapter 24: 447) further argued that non-concurrent, though inter-related, fluctuations in these three mechanisms played a crucial role in driving the dynamics of the trade cycle.

5. Implications for Macroeconomic Modelling and Policy Evaluation

In efforts to improve the quality of teaching and learning there is always a strong temptation to place too much emphasis on disciplinary “content” at the expense of pedagogical considerations. Unfortunately, conventional distinctions between form and content break down from the perspective of process philosophy (Faber, 2000). In sympathy with Marshall McLuhan’s arguments in The Medium is the Message, a claim

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3 In the typical trade cycle it is the marginal efficiency of capital that begins to fall leading, via the multiplier, to a reduction in effective demand. This is usually followed by an increase in liquidity preference on the part of portfolio investors. Finally, wealthy households substitute saving for consumption, whilst debt-deflation transfers income from higher spending borrowers to lower spending lenders.
can be made that “how you teach” generally determines “what is taught”. While this principle is difficult to justify without drawing on theoretical issues of relevance to the discipline, hopefully the brief discussion of these components of monetary theory in the above sections of the paper should have thrown some light on the matter.

No current macroeconomics textbooks begin their exposition of monetary theory by first explaining the nature of vertical links between the consolidated Government (Treasury and the Central Bank) sector and the non-Government sector (banks, households, firms, and the rest-of-the-world), then discussing horizontal links between banks and other agencies. This distinction is essential in both theoretical and pedagogical terms because only vertical transactions create the net financial assets that support the horizontal process of credit creation. The fundamental principle here, is that processes of asset-creation on the part of the banking system, which arise when banks lend money to households and firms, are always cancelled out by the creation of off-setting liabilities—that is, horizontal transactions net out to zero.

The counter-point to this notion, with obvious implications for policy, is that when governments run budget surpluses they are destroying private sector wealth. Stock-flow consistent accounting is a crucial part of this story. It also supplies the grounds for rejecting the all-too common notion that governments are “revenue-constrained”, a situation supposedly made more binding by political moves to make Central Banks more independent from the government’s day-to-day executive functions. The Treasury simply spends by issuing cheques, which no Central Bank is able to “bounce”. Central Bank independence merely amounts to the independent targeting of interest rates on short-term bonds. These interest-rate targets are achieved through open-market operations that either mop-up excess liquidity through the sale of bonds to the non-bank public and inject liquidity through the purchase of bonds from the non-bank public.

While Forrester and Wheat (2007) argue that we learn better from simulation with positive and negative feedback loops rather than from the manipulation of curves on graphs—a useful insight with obvious relevance to disciplines other than economics—the implications of both the Keynesian distinction between short-run and long-run expectations, and Keynes’s psychoanalytically motivated analysis of sublimated and regressive forms of money love, have profound implications for how we should model and simulate policy interventions in real world economies. They open the door to a range of issues familiar to complexity theorists, including stability analysis, how singularities, attractors and bifurcation processes influence the qualitative local behaviour of trajectories, and broader aspects of non-linear estimation and prediction.\(^4\)

\(^4\) On these issues see Vercelli (1991) two separate forms of stability—dynamic and structural (Vercelli, 1991, appendix 3A, pp. 39-40; sections 3.3, pp. 34-5; 3.4, pp. 35-7; and 4.2 pp. 44-5). In his Appendix 4.B3 (pp 62-4), Vercelli examines more formal topological definitions of structural stability. In section 9.2 of his text Vercelli (1991: 143-8) uses block-flow diagrams to criticize the rational expectation framework of Robert Lucas. His main objection to this approach is that “[t]he cognitive process is separated from the decisional one, which allows one to circumscribe the problem of structural instability solely to the formation of expectations.” As a result, “[t]he internal functional structure of the system becomes completely independent of the environment and of the uncertainty, which characterises it.” (Vercelli, 1991: 146).
Yet these issues clearly overlap with pedagogical concerns about “interactivity” and the need to overcome “inert knowledge” comes into play (Petersen, 1999, Schank et al., 1995). While themes of this nature have broad relevance to other quantitative disciplines where interactive techniques are increasingly used as a matter of course (a glance at engineering, biology, and mathematics textbooks incorporating MatLab, Maple, and Mathematica applications should make this clear), few economics texts or courses adequately incorporate model building and dynamic simulation into their teaching material. While econometrics courses do provide students with certain of these opportunities, material on dynamic systems is often avoided because it is seen to be too demanding, difficult, and dry, or to require too much of students in the way of quantitative skills5.

On Winslow’s view, Keynes was convinced that dramatic oscillations between the more regressive and more sublime forms money-love of were responsible for a weakening or strengthening of animal spirits, and for (typically asynchronous) shifts in the marginal efficiency of capital schedules, the marginal propensity to save, and the state of liquidity preference (on the reasons for this asynchrony see Keynes’s famous discussion of the trade cycle in chapter of the General Theory). From an ontological perspective these shifts are correlated with variations in the level of financial fragility. Even from a modern monetary perspective which deems that governments possess the power to set interest rates at will, an increase in liquidity preference will lead to a wider equity premium and, thus, an increase in the weighted marginal cost of capital that is used for the evaluation of investment projects. Accordingly, shifts in these schedules will lead to expansions or contractions of aggregate demand as the consumption and investment components of private expenditure fluctuate. Central Governments must accordingly intervene to mitigate the adverse consequences of these expansions (where they may lead to inflationary outcomes) and contractions in effective demand (where they may lead to lower levels of accumulation, productivity growth and, thus, under-employment, unemployment and under-utilization of capacity). From a modelling perspective, these instabilities in the fundamental behavioural propensities also justified Keynes’s reservations about Jan Tinbergen’s econometric project. However, this does not detract from the need to recognize and model—through simulation—the implications of such fluctuations for modelling the business cycle and informing macroeconomic policy initiatives.

While the global turmoil associated with current financial crisis introduces new opportunities for a shift in macroeconomic paradigms, the very opposite could occur. For example, some conservative business economists are reverting to completely discredited Monetarist theories in arguing that the seeds of the current crisis lie in the United States’s gradual move away from the Bretton-Woods Currency System, the abandonment of money-supply targeting, and the Greenspan policies of “easy money” or low interest rate targets after the dot-com slump in 2001.

5 Ironically, as economics and business courses in Australia become increasingly “dumbed-down”, American Universities are incorporating more quantitative material into their post-graduate business courses (including in market research, logistics, operations research, research methods, and management accounting).
The theoretical core grounding such views is the neoclassical growth model, for which the “natural rate” of growth in output is governed—at the margin—by the real (inter-temporal) forces of productivity and thrift. Accordingly, if they are to gain insight into the limitations of this one-sector model, at an early stage in their academic studies economics students must be exposed, to the implications of the capital debates. In a multi-sectoral, joint-production economy, maximal rates of capital accumulation are governed by the properties of the A-matrix of input-output coefficients and the turn-over rates of capital in each sector (as determined by the Perron-Frobenius theorems applied maximal rates of growth). However, it is of crucial importance to recognize that actual rates of growth can fall well below this maximal level due to an insufficiency of effective demand. It is these insights that justify activist fiscal policies of the part of central governments. Other equally significant implications follow from this theoretical analysis of multi-sectoral growth. In particular, Sraffa’s work established the absence of a numeraire commodity that would remain invariant in value both when there are shifts in income distribution between capitalists and workers and when there the composition of output varies due to the influence of non-constant returns to scale in different industries. This lacuna undermines the prospect for any clear distinction between nominal and real price levels and rates of return. This insight justifies government intervention to set nominal anchors including those supporting the yield structure of interest rates and wage relativities benchmarked against the minimum wage.

5.1 Vertical and Horizontal Transactions and Net financial Assets

The distinction between vertical and horizontal transactions lies at the core of the macroeconomic paradigm that will be advanced by the forthcoming text. The marked difference between vertical and horizontal transactions can be discerned in the current transactions matrix depicted below, which is taken from Dos Santos and Zezza’s (2007) simplified version of a stock-flow consistent macroeconomic model (Lavioe and Godley, 2001-2002).
A Process Philosophy Perspective on an On-line, Macroeconomic Teaching and Learning Project

Here, consumption spending, \( C \), comprises wages after tax, \( W - T_w \), plus a fixed share \( a \), of (lagged) household wealth, \( V_h^\Delta \). Household wealth increases both through savings out of income, the latter including (lagged) interest receipts on deposits, \( i_b \), and dividends received from banks, \( F_b \), and firms, \( F_d \), inclusive of the capital gain on equities (a component subject to minor degree of simplification). Firm investment is \( P \Delta K \), \( i_l \) is the loan rate of interest, and \( T_l \) is the tax rate on firm income. It is further assumed that the government chooses the bill rate of interest, \( i_b \), tax parameters and government spending as proportion of total capital. Likewise, it is assumed that firms distribute a fixed share of after tax profits \( F_d \) as dividends, while banks distribute their total profits \( F_b \) to households. For simplicity, households are assumed to lend all their savings to firms without borrowing themselves.

The last row of the matrix affords a crucial insight into the nature of (vertical) transactions between the government and non-government sectors. These transactions must be clearly distinguished from their (horizontal) counterparts: those between banks, households, and firms. The basis for this distinction is that only vertical transactions give rise to net financial assets or increases in real wealth, whereas horizontal transactions net out to zero. The bottom row indicates that government savings (surplus) or tax revenue net of government spending and payment of interest on bonds \( (T - G - i_b B) \) are equal to the non-government sector’s dis-savings (deficit = \( p \Delta K - F_u - S_h \)). This is a crucial accounting identity because it reveals that when governments run continual budget surpluses, while economic growth could be sustained, this will only happen if the non-government sector maintains on-going deficits, thus accumulating increasing levels of debt. Moreover, as surpluses destroy net financial assets, this increase in private sector
debt will be matched by a continuous decline in net financial assets or wealth. To show this, we must interpret the flow-of-funds accounts more closely.

The sources and uses of funds can be determined by reading the entries in each of the cells in any given column of the matrix. For the household sector, the sources of funds include wages, interest on deposits, and distributed dividends from banks and firms. Uses of funds include consumption and payment of taxes on household income. For firms, sources of funds include revenue from the sale of goods and services to households and government, as well as that component derived from the sale capital goods to other firms. These funds are used for investment, the payment of corporate taxes, the payment of interest on borrowings, and the distribution of dividends. Banks receive interest on loans and issued bank bills, and use their funds for payment of interest on deposits and the distribution of profits.

By summing across the rows for the flow-of-funds accounts of banks, households and firms, it is apparent that all transactions cancel out with the exception of the interest paid on bank bills by government, the payment of taxes by firms and households, and the receipt of revenue by firms for the sale of goods and services to the government. However, these components are all vertical transactions between the government and non-government sectors (see Juniper and Mitchell, 2008).

Extensions of stock-flow consistent modelling to include Rest-of-the-World Accounts are examined in Godley & Izureita (2004: Table 1, 132). Juniper and Mitchell (2008) examine these transactions to demonstrate that government policies of fiscal conservatism in Australia and the US have aggravated private-sector debt ratios.

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<td>Financial Balances</td>
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5.3 Modelling Fluctuations in “Money-Love”

This section of the paper reverts to the model explicated in Dos Santos and Zezza (2007), with the intention of highlighting some of the implications of the preceding discussion of the Whitehead-Keynes-Freud connection. In their model, prices are determined as a mark up (at rate $\tau$) over prime costs (given by the product of the money wage per unit of labour, $w$, and the labour-output ratio, $\lambda$) The authors introduce a banking sector, and decompose private expenditure into consumption, $C$, and investment, $I$, components, and also separate debt liabilities into the stock of bank loans, $L$, and bank bills, $B$. Interest on loans, $i_l$, is represented as a mark up, $\tau_l$, on the bill rate. Banks are assumed to distribute their profits $\pi_b$ entirely to households. Consumption spending, $C$, comprises wages after tax, $W - T$, plus a fixed share of (lagged) household wealth, $V^h$. Household wealth increases both through savings out of income, the latter including (lagged) interest receipts on deposits, $i_b$, and dividends received from banks, $F_b$, and firms, $F_d$, inclusive of the capital gain on equities (a component subject to minor degree of simplification). Investment, $g = \Delta K/K_{-1}$, is decomposed into autonomous amount, $g_0$, an amount represented by a linear function $\alpha\pi + \beta$ of aggregate profit, $\pi$, multiplied by the rate of capacity utilization, $u$, and a negative component, $-\theta\cdot i_l$, responding to the loan rate of interest, $i_l$. It is further assumed that the government chooses the bill rate of interest, $i_b$, tax parameters and government spending as proportion of total capital, $\gamma$. Likewise, it is assumed that firms distribute a fixed share of after tax profits as dividends. The split of household wealth between investments in equities, $\delta$, and bank deposits, $1 - \delta$, is governed by an exogenous “expectations parameter”, $\rho$ and the bank bill rate ($\delta = -i_b + \rho$). Goods market equilibrium in the model determines capacity utilization as a function of autonomous demand components and lagged wealth. The three reduced form model equations that result are listed below. The state variables in the model are bank bill stocks as a proportion of total capital, $b$, and household wealth as a proportion of total capital, $V^h$.

Model Equations

1. $g = g_0 + (\alpha\pi + \beta)u - \theta\cdot i_l$
2. $b = b_{-1}(1 + i^b_{-1}) + \gamma - \theta u \big/ (1 + g)$
3. $V^h = \left\{\left[\left(1 - \delta\right)(1 + i^b_{-1})(1 + \tau_b)(1 - \mu) - a\right]V^h_{-1} + [1 - (1 + \tau_b)(1 - \mu)]i^b_{-1}b_{-1} + \mu(1 - \theta)\pi u\right\} \big/ (1 + g - \delta)$
4. $u = \psi_1 A(i^l) + \psi_1 a V^h$
5. $\psi_1 = 1/[1 - (1 - \pi)(1 - \pi) - \alpha_1]$
6. $A(i^l) = g_0 - \theta\cdot i^l + \gamma$
7. $\pi^b = 1 - \delta V^h$
8. $d = (1 - \delta)\pi^b$
9. $I = (1 - \delta)\pi^b - b$

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10. \[ e = \delta \cdot v^h \]
11. \[ e = \rho_o \cdot E / p.k \]

Household wealth, \( v^h \), grows whenever the increase in household saving (i.e. non-equity household wealth) is faster than the increase in the share of non-equity wealth in total household wealth (represented by the growth of the capital stock \( g \)). This is because increases in investment reduce the price of equities, creating more capital losses the higher the proportion of total household wealth kept in equities.

The authors show that the multiplier, \( \psi_1 = 1/[1 - (1 - \pi)(1 - \theta) - \alpha \cdot \pi + \beta] \) (relating capacity utilization to autonomous expenditure, \( A(i_b) = g_0 - \theta \cdot (1 + \pi_b + \gamma) \), where the bracketed term—denoting sensitivity of expenditure to the bank bill rate, \( i_b \)), is a function of both the “marginal propensity to consume” out of the wage share net of taxes, and the accelerator effect, \( \alpha \cdot \pi + \beta \). The model can be solved recursively with capacity utilization calculated at first, given initial stocks, policy variables, and other parameters (including distributional parameters). This in turn yields values for the growth rate of the capital stock, \( g \), bank bill stocks as proportion of total capital, \( b \), and household wealth as proportion of total capital. Then loan stocks and equities as proportions of total capital and firm wealth can be calculated along with Tobin’s \( q \)-value \( (q = 1 - \text{wealth of firms as proportion of total capital}) \). For stability analysis, the resulting four-equation system can be reduced to two equations in the variables for household wealth and bill holdings, each expressed as a proportion of total capital. Six different regimes obtain depending on key parameter values. Unstable regimes appear to be an unlikely occurrence for the assumed set of reasonable parameter values. Finally, long period equilibrium is derived in an appendix to the paper by setting lagged value of household wealth and bank bills to their current values.

Within this modelling framework, a regression towards more primitive forms of “money love” would be reflected in the following: (a) a diminution of the accelerator effect (as given by \( \alpha \)); (b) an increase in the mark-up on bill interest rates (as given by \( \tau_b \)); and, (c) an increase in marginal savings out of household wealth (as given by \( a \)).

6.0 Concluding Observations

The Whitehead-cum-Keynes perspective outlined in Section 4 of this paper is congruent with a presumption that short-run expectations are generally fulfilled, whereas only the most precarious basis exists for the formation of long-run expectations. This dichotomous approach accommodates the Keynesian argument that increasing financial fragility would result in increasing aversion to uncertainty, being reflected in turn by changes in Keynes’s three key behavioural propensities.

In terms of stability analysis, these changes could conceivably shift the economy out of one more stable regime into another characterised by far less stability\(^6\). Allowing for this

\(^6\) Shifts of this nature are discussed at length both in regard to economic modelling, and in terms of abstract geometric and topology in Vercelli’s under-rated book on Keynes. Vercelli uses block diagrams to suggest
kind of ‘mood shift’ would clearly eliminate the neoclassical presumption (formalized in various separation theorems) that financial determinants can be isolated from real variables because changes in the above-mentioned parameters will alter the rate of capacity utilization.

From the perspective outlined above, while it is highly questionable whether the existing stable of regime-switching and non-linear threshold models could reproduce the richness and complexity of Keynes’s discursive analysis of the trade cycle. However, it is certainly more likely that an appropriately constructed system dynamics models could simulate what happens over the cycle in a Whitehead-cum-Keynesian world. The next step, however, would entail the translation of these models and the insights to be gained from them into more user-friendly pedagogical tools that help to achieve Whitehead’s goal of overcoming “inert” forms of learning.

References


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