Contemporary Systems Thinking

Robert Y. Cavana · Brian C. Dangerfield ·
Oleg V. Pavlov · Michael J. Radzicki ·
I. David Wheat *Editors*

Feedback Economics

Economic Modeling with System Dynamics

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Contemporary Systems Thinking

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ISSN 1568-2846
Contemporary Systems Thinking
ISBN 978-3-030-67189-1 ISBN 978-3-030-67190-7 (eBook)
https://doi.org/10.1007/978-3-030-67190-7

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

This volume is dedicated to the memory of our friend and colleague, Professor Klaus Dieter John (1952–2014), who served as President of the Economics Chapter of the System Dynamics Society and also envisioned this book.

Foreword

Mike Radzicki, on behalf of his co-editors Bob Cavana, Brian Dangerfield, Oleg Pavlov and David Wheat, has asked me to write a foreword for this book on feedback economics and gave me *carte blanche*. Mike is a system dynamics economist who has long been interested in post-Keynesian economics, and I am a post-Keynesian economist who is intrigued by system dynamics. We have in common the attention given to a verbal statement attributed to Michał Kalecki by Joan Robinson: ‘I have found out what economics is; it is the science of confusing stocks with flows’. The sentence is the epigraph on the first page of my book with Wynne Godley, and it is found at the bottom of every email that Mike sends. While Kalecki made this claim around 1936, my experience as a graduate supervisor and a referee is that the confusion still lingers around occasionally. MIT system dynamics Prof. John Sterman (2002, p. 207) also reports that his graduate students often get confused about the consequences of changes in inflows or outflows on stock levels. In his introduction to this volume, Mike mentions that economists ought to think carefully about ‘the stock-flow-feedback loop relationships’ which are at the foundation of dynamic behaviour. In my 2007 book with Wynne Godley, in what is now called the stock-flow consistent (SFC) approach, we have emphasized that the stocks and flows of both real and financial variables must be fully integrated, along with an explicit consideration of their dynamics. And just like Mike in his introduction, we pay homage to Morris Copeland’s conception of money flows. There cannot be any black hole in a model: every financial asset must have a counterpart liability, and for each outflow there must be an inflow in some other sector.

Over the past 15 years several macroeconomic system dynamics models were produced that embodied elements of the post-Keynesian-institutionalist paradigm, but also contained many neoclassical formulations. In this respect, I see many similarities between system dynamics and agent-based modelling: both approaches can entertain orthodox or heterodox features, or a mixture of both. Human behavior in system dynamics, as described by Sterman (1987), is no different from the behavior formalized in the evolutionary agent-based models of Dosi et al. (2010), or in the post-Keynesian agent-based SFC models of Caiani et al. (2016) and Seppecher et al. (2018). They all rely on the insights of what can be called old or original behavioral economics—Herbert Simon as well as Cyert and March—and more recently on those of Gerd Gigerenzer (2008). These common insights are that one cannot use future variables when constructing a model: there are limitations to the cognitive capabilities of economic agents, first to gather appropriate information, and then to treat this information and arrive at an enlightened decision. Heuristics and routines, along with target ratios and satisficing, are the core tools of human behavior. Optimization under constraints is ruled out. As Radzicki (2010, p. 6) notes, and it could as well apply to post-Keynesians and heterodox agent-based modellers, 'the commitment to modeling actual human decision-making forces system dynamicists to turn to cognitive psychology for insights into how humans cope in an uncertain world. It also ensures that a system's overall macro behavior emerges from a realistic micro structure'. Interestingly, Dosi et al. (2020, p. 1512) conclude from their study of various forms of expectations in their Schumpeterian-Keynesian agent-based model that 'in the presence of deep uncertainty, technical change and structural breaks, the best "evolutionary" response of firms seems to be the adoption of *heuristics*'.

Besides the concern for stocks and these microeconomic features, there are also methodological features that system dynamics and post-Keynesian economics share. The system dynamics modeling process begins with a problem or question that is stated in dynamic form by time-series graphs of variables that are behaving problematically. The modeling process is aimed at defining an endogenous causal explanation for the problematic behavior. Causality, with story telling, is also crucial for post-Keynesians. In the specific case of stock-flow consistent models, the work originates from some problems or puzzles in the "real world" economy. The SFC methodology was always used by Godley, in his own words, as a "tool for thinking" on what was happening to the economy, and he never made a claim that what he had developed was the "true" model (Lavoie and Zezza, 2012, pp. 14–15). Sterman (2002, p. 525) says something similar: "We can never place our mental models on a solid foundation of truth because a model is a simplification, an abstraction, a selection, because our models are inevitably incomplete, incorrect—wrong".

Another crucial feature of system dynamics, as the title of the present book underlines, is the importance of feedback mechanisms. These are also present in post-Keynesian economics and in SFC models. There is however a difference on how system dynamics economists and SFC economists would proceed. I tend to instruct graduate students to first focus mostly on the so-called negative (balancing) loops, so as to obtain a stationary state or a steady state, from which one can pursue some experiments by changing the value of a parameter and examining the impact of the change on the main variables of the model. I believe it is best to introduce (most) positive (reinforcing) loops in a second step. I believe this is instructive, as the modeller can see whether the introduction of a given positive loop or of an additional non-linearity changes the overall behaviour of the model, for instance by driving it into an explosive mode. Another reason for following this strategy is that large SFC models can be difficult to get going, as over-ambitious graduate students or newcomers soon find out.

There have been a few efforts in the past to link up post-Keynesian economics with system dynamics. I have in mind an early effort by Saeed and Radzicki (1993), and articles by John Harvey, which describe Keynes' theory of the business cycle (2002) and various formulations of deviations from the uncovered interest parity (2006) with figures based on a system dynamics approach. Radzicki (2008) presents his version of a post-Keynesian/Institutionalist/System Dynamics macroeconomic model, which contains in particular an extensive formulation of wage determination and of pricing by large corporations, inspired mostly by the work of Alfred Eichner.

With the arrival of the Global Financial Crisis, the financial fragility hypothesis of Hyman P. Minsky has been brought into the limelight, with Wall Street observers referring to the Minsky moment. But the work of Minsky was always popular among post-Keynesian scholars, even before the 2008 crisis. Éric Tymoigne (2006) has a quite complex stock-flow consistent model based on Minsky's insights and constructed on a system dynamics platform. His model describes the cash-flow commitments of firms, as well as their investment and pricing decisions, along with the production decisions relative to the sales level. More recently, Steve Keen has built a system dynamics platform called *Minsky,* also based on stock-flow consistent scriptures and double-entry bookkeeping, where financial instability can be observed.

With the publication of *World Dynamics* (Forrester, 1971) and *The Limits to Growth* (Meadows et al., 1972) in the 1970s, system dynamics became associated with ecological economics. Post-Keynesians were slow to deal with ecological concerns, as they debated with their neoclassical colleagues against the necessity of monetary and fiscal austerity for full employment and economic growth. Post-Keynesians have now started to confront the looming ecological crisis with models that combine effective demand with ecological constraints. It is interesting to note that the well-known ecological economists Tim Jackson and Peter Victor (2015; 2016) have designed SFC models with system dynamics, which are essentially based on post-Keynesian theory and often relying on the formalization found in Godley and Lavoie (2007).

Indeed, Radzicki (2020) presents a system dynamics representation of the simplest of Godley and Lavoie's models (2007, Chap. 3), as a straightforward example of a model based on a traditional difference equation approach. Another system dynamics model in Godley and Lavoie (2007, Chap. 9) captures a complex situation with a relatively simplistic structure containing only three sectors—households, firms and banks, with the latter only making loans and holding deposits. The model takes inventories into account—a feature often ignored in mainstream models—and distinguishes between nominal and real magnitudes, integrating real and financial variables. Clearly, there is much space for more collaboration between the advocates of post-Keynesian economics and system dynamics! More generally, I would like to recommend this book to all scholars and practitioners interested in exploring the interface and synergies between economics, system dynamics, and feedback thinking.

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Preface

This book emerged from ideas and discussions over several years of our active involvement with the Economics Chapter of the System Dynamics Society. We want to encourage more economists to add feedback analysis to their tool kits. All of us had formal training in traditional economic theory and we are convinced that system dynamics can add a useful new perspective to economic analysis.

The fundamental principle of system dynamics is that a system's structure is responsible for its characteristic behavior. Economic systems are complex feedback structures containing positive (reinforcing) loops that encourage growth and negative (balancing) loops that promote convergence. The resulting battle of competing loops, each containing at least one delay-inducing stock and its flow, drives the complex behavior that emerges from those systems. The system dynamics method offers a robust way of developing mathematical models of economic systems and checking for stock-flow consistency. Moreover, diagrams that display stock-flow-and-feedback relationships encourage transparency and intuitive understanding of the causal hypotheses contained in a model's structure.

The origin of system dynamics can be traced back to 1958, when an MIT engineer named Jay W. Forrester (1918–2016) published a paper describing a dynamic model in the *Harvard Business Review* that provided a new way of thinking about business firm structure and behavior. Originally called industrial dynamics because of the early focus on the microeconomics of firms, the field was renamed system dynamics as Forrester and his colleagues and students explored broader applications, including public policy, resource scarcity, and issues in finance and macroeconomics.

The financial crisis of 2008 sparked a renewed interest among economists and policy makers in the relative strengths and weaknesses of alternative methods of economic analysis and modeling. Thus, an additional objective of this book is to encourage innovation and promote pluralism within the economics profession. This volume is intended for instructors, researchers, graduate students, and policy analysts interested in understanding economic issues from a systems thinking and feedback perspective. It should be of particular interest to researchers engaged in analysis and policy design for real-world economic systems.

While we take pride in this collection of chapters illustrating the applications and techniques of system dynamics modeling, we know that one book cannot provide a comprehensive foundation in these methods. Fortunately, there are now several programs around the world offering courses and degrees in system dynamics modeling. More information is available on the website of the International System Dynamics Society (https://www.systemdynamics.org).

The scope of this volume reflects our intention to expose readers to a variety of examples of how system dynamics methods can be applied to economic issues. The book contains twenty chapters that address economic issues and theories from a systems thinking and feedback perspective. In addition, supplementary materials available online provide access to many of the simulation models described by the chapter authors. Following a brief introduction to the concepts and history of feedback economics, the chapters are organized in five parts, as follows:

- Part I *Macroeconomics*—Getting started with macro modelling using system dynamics; a feedback approach to analysing economic equilibrium, instability and growth; the process of money creation; and a digital translation of the famous mid-20th century MONIAC analog computing machine for a macro economy.
- Part II *Microeconomics*—A feedback model of organized crime; a comparison of econometric and system dynamics calibration approaches for market growth models; and a feedback theory of redistribution.
- Part III *Resource Economics*—A re-examination of classical economic theories of the limits to growth; the development of a biophysical module for a global economy model; modeling of ecological-economics systems; and a re-examination of a natural resource curse.
- Part IV *Policy Analysis*—A model to evaluate different policies for addressing sovereign debt induced banking crises; modelling the relationships between sovereign debt default and currency crises; balancing the complexity of economic growth and environmental impacts using copper as a case study; and a macroeconomic analysis of profit sharing and job creation.
- Part V *Variations and Reflections*—Feedback analyses of classical economic theories of Harrod and Hicks; a theory of well-being as a complex interconnected system; and a study that demonstrates the importance of a review-and-reflections stage for a modeling process.

Our hope is that you will find the contents of this book and the supplementary materials interesting, informative and, at times, challenging. All the best with your journey into 'Feedback Economics'!

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Bristol, UK	Brian C. Dangerfield
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October 2020	

Acknowledgements

We would like to thank the contributing authors for their thorough and insightful research at the intersection of economics, systems thinking and system dynamics presented in this book.

We also thank our many reviewers, whose helpful comments and suggestions have greatly improved the quality of the book: Dan Arthur, Souleymane Bah, Henry Bartelet, Carmine Bianchi, Christine Bolton, Tatiana Boyarskaya, Tim Clancy, Newton Bueno, John Cody, David Collste, Pervin Dadashova, Graeme Doole, Oleksandr Faryna, Vicky Forgie, Jim Hacunda, Johannes Hartwig, Mike Joffe, Anne Johnson, Marianna Oliskevych, Saeed Langarudi, Jide Lewis, Richard Logan, David Pearson, Matthias Pfaff, Bill Ryder, Khalid Saeed, Martin Schaffernicht, Rodney Scott, Valerijs Skribans, Kaoru Yamaguchi and Raafat Zaini.

Finally, we wish to express our gratitude to the staff at Springer Nature for their ongoing encouragement and support, which has been especially important as we worked to finish the book in the midst of the Covid-19 crisis.

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Robert Y. Cavana is currently an Adjunct Professor (previously a Reader in Systems Science) with the Wellington School of Business and Government, Victoria University of Wellington, New Zealand (NZ). He holds a master's degree in Economics from the University of Auckland, NZ (where he was a graduate student of Prof. A. W. H. (Bill) Phillips in Economic Dynamics), and a Ph.D. in Management (System Dynamics) from the University of Bradford, UK. Prior to entering the academic world in 1989, he was the Corporate Economist with the NZ Railways Corporation. He is a past President of the NZ Operational Research Society, a past President (Economics Chapter) and Vice-President of the International System Dynamics Society, and a former Managing Editor of *System Dynamics Review*. He was a NZ representative and Company Secretary on the Executive Board of Australia & New Zealand Academy of Management and is currently a Fellow of ANZAM.

Professor Cavana received the Hellenic Society for Systemic Studies Honorary Award as "Distinguished Scientist in the Scientific area of Systems Approach" in 2009. He has published in a wide range of international journals, including *System Dynamics Review, Systems Research and Behavioral Science*, *European Journal of Operational Research, Journal of the Operational Research Society* and the *American Journal of Public Health.* He is a co-author of *Systems Thinking, System Dynamics: Managing Change and Complexity* 2nd edition (Pearson Education, Auckland, 2007) and *Applied Business Research: Qualitative and Quantitative Methods* (Wiley, Brisbane, 2001; Chinese edition 2004). He recently co-edited the *Systems* online special issue and book on *Systems Education for a Sustainable Planet* (MDPI, Basel, Switzerland, 2018).

Brian C. Dangerfield is currently employed in the School of Management at the University of Bristol, joining in 2014. After a short spell in industrial Operational Research, he was hired by the University of Liverpool, UK before moving on to the University of Salford where he was promoted to a Chair in Systems Modelling in 2000. Educated in the UK, he holds a bachelor's degree in Economics, Statistics &

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Professor Dangerfield's research interest is in the application of system dynamics (SD) simulation models to policy-level issues in economics, business, health and public policy generally. Numerous journal articles have resulted from this work. He is editor of the book *System Dynamics: Theory and Applications* (Springer, 2020) and a co-editor of *Discrete-Event Simulation and System Dynamics for Management Decision-Making* (Wiley, 2014).

He was awarded the UK Operational Research Society's President's Medal in 1991 and their Goodeve Medal in 2006, both awards being for health-related papers applying the system dynamics methodology. During 2009/10 he served as the President of the Economics Chapter of the International System Dynamics Society and for the ten years to 2011 he was Executive Editor of the *System Dynamics Review*. In 2018 he was awarded a gold medal from the UK System Dynamics Society for an Outstanding Contribution to UK System Dynamics.

Oleg V. Pavlov is an Associate Professor of Economics and System Dynamics at Worcester Polytechnic Institute (WPI) in Massachusetts. He uses simulations and systems thinking tools to study causal feedback effects in complex social and economic systems. His research has been published in the *System Dynamics Review*, *Computational Economics*, *Journal of Economic Issues*, *Journal of Economic Dynamics and Control*, *Journal of the Operational Research Society*, *PLoS ONE* and the *Handbook of Service Science*. He has taught in the USA, Finland, China, Russia, and the UK. Additionally, he is involved in K-12 outreach programs at WPI. He has been a campus coordinator and coach for the system dynamics fair for school students called DynamiQUEST. He was lead-faculty for Exxon Mobil Bernard Harris Summer Science Camp, and he was the director of a summer program that taught children how to model environmental systems.

He serves on the editorial boards of the *System Dynamics Review* and the *Entrepreneurship Research Journal*. Professor Pavlov is a past President of the Economics Chapter of the International System Dynamics Society and he was a Coleman Foundation Faculty Entrepreneurship Fellow. He earned a Ph.D. and a master's degree in Economics and a bachelor's degree in Physics and Computer Science from the University of Southern California. He also holds an MBA from Cornell University.

Michael J. Radzicki is an Associate Professor of Economics at Worcester Polytechnic Institute in Worcester, Massachusetts, and the creator of WPI's program in system dynamics computer simulation modeling. He received his Ph.D. in economics from the University of Notre Dame and his training in system dynamics modeling from the Massachusetts Institute of Technology.

Professor Radzicki's research lies at the interface of system dynamics and economics and he has served on the editorial boards of several academic journals. In

2004 he served as the inaugural president of the Economics Chapter of the System Dynamics Society, and in 2006 as president of the System Dynamics Society.

I. David Wheat is Emeritus Professor of System Dynamics at the University of Bergen in Norway, visiting Professor of Economic Dynamics at the National University of Kyiv-Mohyla Academy in Ukraine, and visiting Professor of Monetary Policy at ISM University of Management and Economics in Lithuania. A key component of his macroeconomics instruction has been the use of *MacroLab*, a simulation model he created in 2000 to demonstrate and explain simple macroeconomic dynamics to undergraduates. A *MacroLab* Template has evolved over the past twenty years and is now a framework for constructing and comparing more complex macro models and for teaching graduate students.

For nearly a decade, he has collaborated with Ukrainian economists to build dynamic modeling capacity at universities in Kyiv and Lviv, and that has extended to work on a monetary policy model with economists at Ukraine's central bank and an economic policy strategy model for recovery of the war-torn eastern region. Professor Wheat also collaborates with public policy scholars to improve the practical value of system dynamics models by adding implementation insights gleaned from the public policy literature.

During the early 1970s, Wheat served at the White House as staff assistant to the President of the United States. For three decades before joining academia, he managed his own consulting firm. He also served as President of the Economics Chapter of the International System Dynamics Society and as Associate Editor of the *System Dynamics Review*. He received his Ph.D. in system dynamics at the University of Bergen, a master's degree in public policy at Harvard University, and a bachelor's degree in government and mathematics at Texas Tech University.

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Chapter 1
Introduction to Feedback Economics

Michael J. Radzicki

1.1 Introduction

Economists have studied the "magnificent dynamics" of economic systems since at least the time of Adam Smith.[1] At the macroeconomic level, much of the analysis has traditionally looked at the trend (growth theory), the cycle (business cycle theory)[2], or with the advent of computer simulation and nonlinear modeling, the endogenous interaction between the trend and the cycle.[3] Although evolutionary economists such as Marx, Veblen, and Schumpeter developed very comprehensive descriptive socioeconomic theories, they were, at their core, primarily concerned with the unfolding dynamics of the economy. Again, with the emergence of computer simulation technologies, it became possible for economists to formally model the evolutionary change inherent in the theories of these great thinkers.[4]

At the microeconomic level, economists have traditionally examined the dynamics of firms, households, individual markets, and even entire industries.[5] Samuelson famously developed his correspondence principle to determine the circumstances under which comparative static analysis yielded the same (stable) results as dynamic analysis, thus making the use of difference or differential equation modeling in those situations unnecessary.[6] That said, when economists inevitably turn to dynamic

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[1]See Baumol (1951), Nachane (2007), and Harris (2008).

[2]See the overview in Rosser (1999).

[3]See Goodwin (1953).

[4]See Saeed (2020).

[5]Of course, much of modern macroeconomic modeling involves the incorporation of microeconomic foundations. In the world of feedback economics see Forrester (1979, 1980), Saeed (2015), and Laidler (2008).

[6]See Samuelson (1947).

R. Y. Cavana et al. (eds.), *Feedback Economics*, Contemporary Systems Thinking,
https://doi.org/10.1007/978-3-030-67190-7_1

modeling, they typically choose to represent time discretely and thus to utilize a difference equation approach. This is probably due to the well-defined schedule according to which economic data are periodically released.

1.2 The Origin of Economic Dynamics

The preceding observations about economic dynamics lead directly to the following question: What causes economic systems to change over time? MIT Professor Jay W. Forrester, the creator of system dynamics computer simulation modeling, argued convincingly that change over time is caused by the process of accumulation—i.e., the process of flows being accumulated (integrated) in stocks. Indeed, Forrester would often say that “nature integrates, it doesn’t take derivatives.”

Of course, economists have long been familiar with the concept of stocks and flows, and some of them explicitly tied the concept directly to economic dynamics. To cite just a few examples, in the late 1940s, Copeland (1949) conceived of money flowing through an economic system as analogous to the flow of electricity in an electrical circuit. At about the same time Bill Phillips created a hydraulic machine that kept track of the flow of water into and out of reservoirs (stocks) and then plotted the water levels over time.[7] In 1950, Kenneth Boulding famously suggested reconstructing economics around the concept of the balance sheet,[8] and Post Keynesian economists began building “stock-flow consistent” models in the 1980s.[9]

Although economists certainly think about dynamic behavior and sometimes even tie their thoughts directly to stocks and flows, they rarely think explicitly about the notion of feedback. This is unfortunate as stocks and flows do not exist in isolation, but rather as part of interconnected networks of feedback loops. Feedback is the transmission and return of information about the “state” of a system, i.e., about the amount of “stuff” that has accumulated in each of a system’s stocks over time. This information travels throughout a system and eventually returns to the flows that fill or drain the stocks, thus closing the system’s feedback loops. Generally speaking, the information being transmitted via feedback loops is used by agents to make decisions that alter a system’s flows and cause the system to adapt its behavior over time.

Two types of feedback processes exist in socioeconomic systems: positive (reinforcing) loops and negative (balancing) loops. Positive loops represent self-reinforcing processes and, generally speaking, are responsible for the growth or decline of systems. Economic growth trends, multiplier processes, accelerator relationships, wage-price spirals, speculative bubbles, bandwagon effects, increasing

[7] See Phillips (1950), Barr (1999), and Ryder and Cavana (2021; this volume).

[8] In a letter to Randy Wray, Boulding wrote that: “I still think that I was right that economics should be built around a kind of demography of commodities, with a clear distinction between the ‘flashlight photograph,’ that is, the population of goods at a moment of time, which is, of course, capital, and then going on from that to the ‘movie,’ a succession of frames or events, which, of course, is income.” See Boulding (1950) and Wray (1997, p. 449).

[9] See for example Godley and Cripps (1983) and Godley and Lavoie (2012) and Godley (2004).

returns, path dependent processes,[10] and anything that can be described as a vicious or virtuous circle can be represented with positive feedback loops. Negative loops, on the other hand, represent goal-seeking processes and many types of purposeful behavior. They can either stabilize systems or cause them to oscillate when their corrective action is delayed (by stocks). As such, negative loops are responsible for such things as the "invisible hand" equilibrating processes of well-functioning markets and the unstable behavior of macroeconomic cycles. During the accumulation process, a system's positive and negative feedback loops battle for dominance and, in so doing, determine the system's path over time. At the macroeconomic level, the rivalry between the two types of loops determines the details of the interaction between the trend and the cycle.

Heterodox economists who favor non-equilibrium explanations for the dynamics of economic systems often integrate Gunnar Myrdal's concept of "circular and cumulative causation" into their analyses.[11] At first pass, the phrase conjures up the notion of "stocks and flows and feedback loops." Indeed, Kapp (1976, p. 220) has written that it is a foundational principle of economics:

> …it is justified to regard the principle of interlocking circular interdependencies within a process of cumulative causation as the "disciplinary matrix" which provides…economists with a new tool for the identification and ordering of the relevant elements in the study of socioeconomic processes in their immensely diversified and changing complexity. More than this, the principle enables [economists] (and other social scientists) to transform problematical situations and unsolved open problems…into "puzzles" which can be solved even when a complete theory and the precise knowledge as to the "coefficients of interaction" are not [yet] available."

O'Hara (2008), on the other hand, notes that the concept of circular and cumulative causation really only applies to positive feedback loops and hence to non-equilibrium processes such as economic hysteresis and path dependence.[12]

In the early 1980s, Richardson (1983, 1999) identified two main streams of thought from which the feedback concept entered the social sciences. The first was the cybernetics thread, which was pioneered by scholars such as Wiener (1948) and the participants of the Macy Foundation Conferences, and introduced into economics by economists such as Lange (1970), Kenneth Boulding (1974), and Eichner (1987).[13] The second was the servomechanism/control engineering thread pioneered by scholars such as Tustin (1953), Phillips (1954), Forrester (1956),[14] Allen (1956), and Axel Leijonhufvud (1968).[15] Richardson (1983, 1999) argues convincingly that thinkers within the cybernetic thread only emphasize negative

[10] See David (1985).

[11] See Myrdal (1957), Kaldor (1972), Kapp (1976), O'Hara (2008), and Berger (2009).

[12] See David (1985), Davidson (1993), and Belke et al. (2014).

[13] See the discussion in Radzicki (2010).

[14] Again, see Saeed (2015).

[15] Cochrane and Graham (1976) note that "Axel Leijonhufvud has referred to the introduction of control engineering into [macroeconomic] analysis by Tustin, Phillips, and others in the 1950s as 'the Keynesian Revolution which did not come off.'".

feedback processes, as feedback is simply viewed as a mechanism of homeostasis and control, whereas thinkers within the servomechanism/control engineering thread emphasize *both* positive and negative loops, as they are seen as intrinsic pieces of actual systems and not as merely possible mechanisms of external control. The servomechanism/control engineering thread is the one most closely related to system dynamics modeling and to the chapters presented in this volume.

1.3 This Book

Feedback Economics is divided into five distinct parts, each of which represents a thematically related set of applications of the stock-flow-feedback loop concept to economics.

Part I is devoted to macroeconomics and the conceptualization of economic systems from a feedback point of view. The chapters in this part cover a variety of topics including instructions for getting started with macroeconomic modeling via a feedback perspective using a template based on a system dynamics model called MacroLab (Wheat et al., 2021), a chapter presenting a variety of economic concepts via causal loop diagrams (Joffe, 2021), an outline of a system dynamics macroeconomic model that correctly represents and integrates the stock-flow structure of the financial and real economies (Yamaguchi & Yamaguchi, 2021), and a system dynamics representation of the well-known Phillips machine (Ryder & Cavana, 2021).

Part II is devoted to microeconomic dynamics. The chapters in this part range from an examination of the origins of organized crime in Italy (Pavlov & Sardell, 2021), to a comparison of calibration techniques for market growth models in the telecom industry (Arthur, 2021), to an analysis of the "paradox of redistribution" from a dynamic feedback perspective (Collste, 2021).

Part III explores the dynamics of resource use and sustainable development from a dynamic feedback perspective. The chapters in this part include a presentation of dynamic feedback models representing "limits to growth" concepts in the work of Adam Smith, David Ricardo, Thomas Malthus, Karl Marx, and Joseph Schumpeter (Saeed, 2021), a chapter describing the latest contribution in the line of *World Dynamics-Limits to Growth* sustainable development models (Sverdrup et al., 2021), an overview of the contributions to ecological economics from system dynamics modeling (Uehara et al., 2021), and finally, a dynamic re-examination of the "natural resource curse" paradox (Langarudi & Radzicki, 2021).

Part IV is devoted to policy analysis. Generally speaking, system dynamics modeling is used to generate insight among policy makers that can lead to the redesign of the stock-flow-feedback loop structures inherent in the complex systems they seek to understand and control. The chapters in this part utilize dynamic feedback modeling to develop policies aimed at enhancing system stability in the banking sector and at avoiding currency crises (Lewis & Dangerfield, 2021; Boyarskaya, 2021), efficiency in the use of raw materials (Hartwig & Pfaff, 2021), and mitigating capital over-accumulation and the struggle over wages and profits in capitalist systems (Ryzhenkov, 2021).

Part V completes the volume by presenting chapters offering variations on, and extensions to, traditional economic and system dynamics modeling. Contributions include a rethinking of the infamous "knife-edge" in the Harrod growth model (Radzicki, 2021), a reformulation of Sir John Hick's classic multiplier-accelerator model through the addition of a missing lag structure (stock) (Keen, 2021), a chapter describing the creation of a feedback-based regional well-being index through group modeling building interventions (Forgie et al., 2021) and, finally, a re-examination of a system dynamics model of the New Zealand economy (Cavana, 2021).

Our hope is that *Feedback Economics* will motivate economists to begin thinking about the dynamic behavior of economic systems in terms of the stock-flow-feedback loop relationships that form the foundations of their structures. This perspective is simultaneously unique, insightful, and grounded in the rich history of economic thought. It may also lead to new perspectives on the economic problems of the day.

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