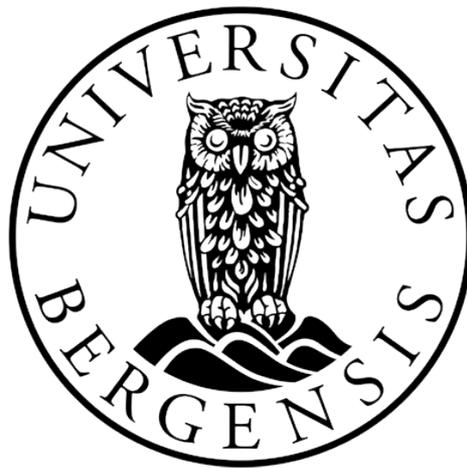


The Feedback Method

A System Dynamics Approach to Teaching Macroeconomics

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Dissertation for the degree philosophiae doctor (PhD)

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*To Cynthia,
who made it possible.*

The Feedback Method: A System Dynamics Approach to Teaching Macroeconomics

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Abstract

JEL: A22, C91, E21, E23, E32

Key Words: conceptual change, dynamics, education, feedback, macroeconomics, mental model, simulation, value added

This thesis documents a method for improving undergraduate instruction in macroeconomics. Called the *feedback method*, it enables students to learn about dynamic behavior in a market economy by using feedback loop diagrams and interactive computer simulation models instead of static graphs or differential equations. There are at least two types of pedagogical problems associated with graphical representation of the economy. First, students seem to have difficulty interpreting static graphs used to illustrate dynamics, which raises questions about the value added by graphs to student understanding. Secondly, the most prominent graph in modern macroeconomics principles textbooks—the aggregate supply and demand (AS/AD) model—appears to misrepresent disequilibrium conditions in the economy and cause students who understand the graph to misunderstand important behavior in the economy.

The feedback method emphasizes *dynamics* rather than static equilibrium conditions. How the economy changes over time in different contexts is the behavioral question that students repeatedly encounter. The structure of the economy is explained in terms of reinforcing and counteracting *feedback loops*. Student understanding of the source of dynamic economic behavior requires seeking, identifying, and explaining relevant feedback structure in an economic system. Interactive computer simulation activities reinforce the insights gained from studying feedback loops. Even small-scale student participation in model-building seems to facilitate understanding of a larger model; moreover, such participation may build respect for the scientific method and an appreciation for theory building by economists.

The feedback method is a structural explanation of economic behavior, but it also provides an improved *learning structure* for students, and the thesis reports on four experiments designed to test that claim. Two experiments examined student *preferences* for methods of learning macroeconomics; for example, using static graphs or a feedback loop diagram. The experimental designs were quite different, but the results were the same—a significant majority preferred the feedback method. The most commonly cited reason: feedback loops enable the students to visualize a *process* in the economy. The third and fourth experiments addressed the *performance* question. In the third experiment, students showed more understanding of GDP when they had access to a stock-and-flow feedback diagram of the economy. In the final experiment, students using feedback loop diagrams displayed more understanding of business cycle dynamics than other students who had access to an AS/AD graph. Teaching students to search for feedback structure in the economy and using computer simulation to connect structure with behavior appears to be a promising method for teaching macroeconomics.

Acknowledgments

I will be forever grateful to my colleagues in the system dynamics group at the University of Bergen, professors Erling Moxnes and Pål Davidsen, for their professional guidance, their confidence and support, and their genuine interest in my work. Erling was my principal adviser on this thesis, and his expertise, good judgment, and encouragement have been invaluable.

I particularly value the opportunity to serve as senior lecturer in system dynamics during this time. It has been an inspiration to work with these outstanding international master's students. I also appreciate the support of professor Anders Lundberg, chairman of the geography department, and other colleagues who have made me feel at home in this department. At the same time, long-distance support was being provided by professors James Sargent and Inez Farrell, social science dean and director of instructional technology, respectively, at Virginia Western Community College in Roanoke, Virginia. They gave me the opportunity to utilize distance learning technology and continue teaching economics in Virginia while residing in Bergen. And I owe a debt to my Virginia students who have been using progressively refined versions of the feedback method to learn macroeconomics over the past five years. They could not have gained as much from the experience as I did.

Jay W. Forrester, Professor Emeritus of Management at the Massachusetts Institute of Technology, had an early vision of system dynamics as an instructional tool across the curriculum. That vision has been a stimulus for me and for a cadre of instructors in both higher education and K-12 who have been at this for two decades or more. A special thanks goes to Diana Fisher and Larry Weathers, two SD pioneers at the K-12 level, who conducted experiments for me in Oregon and Massachusetts.

In the long days leading to the finish, many colleagues and friends volunteered to help, and particularly valuable assistance came from those who read drafts and had suggestions on how I might make my points a little more clearly. Mihaela Tabacaru, a PhD student in the system dynamics group, was especially helpful, as were visiting professors Steve Alessi and Martin Schaffernicht.

Finally, the greatest appreciation is reserved for my wife, Cynthia, and not just for her valuable proofreading skills. Her sacrifices in the interest of my career began long ago but certainly reached a pinnacle in Bergen. Without her love and support, this project would never have begun and would never have succeeded.

Preface

What Des-Cartes did was a good step. You have added much several ways, & especially in taking ye colours of thin plates into philosophical consideration. If I have seen further it is by standing on ye shoulders of Giants.

--Newton to Hooke, 5 Feb. 1676

No claim is made here that “standing on the shoulders of giants” has enabled me to see further than others. Without doubt, however, it has improved my own vision. The research that is the foundation for this thesis has been motivated by an overarching goal of improving economics education at the undergraduate level. An argument will be made that a new approach to teaching macroeconomics—the *feedback method*—improves learning of dynamic behavior in a market economy. The approach may be new, but the motivation is not unique. Countless others have devoted large parts of their professional lives to improving economics education.

Economists’ institutional concern about the content and delivery of economics instruction spans more than half a century. In 1955, the American Economic Association established its Committee on Economic Education for the purpose of improving the quality of economics education. With growing interest in empirical analysis of teaching at the college level, the *Journal of Economics Education* was established in 1969. About twenty years later, *Computers in Higher Education Economics Review* began publishing papers related to the use of information technology in economics education. In 2003, the latest peer-reviewed journal—the *International Review of Economics Education*—was launched, fittingly, on the Internet. Hundreds of regional, national, and international conferences, workshops, and panels on economics education have been held over this period, most recently at the January 2007 Allied Social Sciences Association Conference in Chicago, Illinois. The agenda for the June conference of the International Confederation of Associations for Pluralism in Economics includes a panel session devoted to “Teaching Economics with System Dynamics.” In September, the annual Developments in Economics Education Conference will be held at Cambridge University in the UK.

Within the interdisciplinary system dynamics (SD) community, the motivation to improve understanding of economic systems came nearly fifty years ago with Jay W. Forrester’s seminal call for a new kind of economics education, a call that he has renewed in the K-12 education setting in recent years. John Sterman’s encyclopedic *Business Dynamics* is a symbol not only of the breadth of his own economic policy and management research and teaching but also the range of work done by others in this field. Teaching the economics of resource management with system dynamics tools has been the devotion of Andrew Ford and Erling Moxnes. James Lyneis took his management consultant’s expertise into the university classroom and developed an SD-based microeconomics course. Economists Michael Radzicki and Kaoru Yamaguchi have developed complete graduate-level economics courses on a system dynamics foundation. An informal survey produced this list of others who have used SD as a teaching tool in economics courses: Glen Atkinson, Scott Fullwiler, John Harvey, Steve Keen, Ali Mashayekhi, Jairo Parada, Oleg Pavlov, Khalid Saeed, Jim

Sturgeon, Linwood Tauheed, Pavlina Tcherneva, Scott Trees, Eric Tymoigne, Lars Weber, and Agnieszka Ziomek, and that is surely just a fraction.

In that spirit of innovation, this thesis has been written. It is dedicated to improving economics education, and it develops a pedagogical method that complements diverse theoretical perspectives and instructional strategies. Nearly five years in development, the research product documented in this thesis is motivated by the conviction that economics warrants a wide audience and is neither inherently dull nor hopelessly difficult. The emphasis here is on macroeconomics and a feedback method that enables undergraduates to experience dynamics even when they lack the mathematical tools that advanced students use to explore that vast—and politically relevant—territory between the shores of equilibria.

While wedded to no specific school of thought, the feedback method does have its prerequisites. The first is a belief that transitions between equilibrium states are important and that early access to dynamics is beneficial to students. Second is an appreciation for both the forest and trees—how the pieces fit together at the micro level to produce the behavior observed in macroeconomic systems. The final requirement may be the most demanding because it is rare, almost an oxymoron: an innovative spirit that is skeptical of silver bullets. No single pedagogical method can revolutionize learning in economics or any other field. However, annual improvements averaging just five percent will double the quality of instruction twice during a typical faculty career. The feedback method is promising without making unwarranted promises. Instructors seeking ways to make the next marginal improvement in their current teaching strategies may find it useful.

The thesis begins with an introduction that summarizes the rationale for the feedback method, its methodology, and evidence of its value in both real and experimental settings. The first paper aims to provide interested economists outside the SD community with some tools for integrating the feedback method with their current teaching strategies. The next four papers constitute the proof of the pudding, as it were. There, readers will find the feedback method put to the test in controlled experiments. The underlying system dynamics computer model and its interactive learning environment—together, called *MacroLab*—are documented extensively in the remainder of the thesis.

This product is intended for sharing with colleagues—known and unknown—who see it as a potentially useful tool. Like all tools, it will need sharpening and re-shaping from time to time, and I invite and encourage those who are so inclined.

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2. Student Preferences when *Explaining* Dynamics
3. Student Preferences when *Learning* Dynamics
4. Do Stock and Flow Feedback Diagrams Promote Learning in Macroeconomics?
5. Teaching Business Cycle Dynamics: A Comparison of Graphs and Loops

MacroLab Documentation

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2. The Interactive Learning Environment

Introduction

Writing the lead article in the inaugural issue of the *Journal of Economic Education*, Kenneth Boulding envisioned it as a journal that could “facilitate the rapid assimilation of a large body of empirical observation.” (Boulding, 1969) When the *International Review of Economics Education* was launched, editors Peter Davies and Carol Johnston emphasized their interest in “papers that debate the nature of the economics curriculum” since “regular critical scrutiny” is needed to keep curricula from becoming “ossified.” Like Boulding, they expect “careful statistical analysis of evidence in economics education.” (Davies and Johnston, 2003) These comments indicate a continuing demand for rigorous appraisal, even when that means appraising the sacred cows.

Six years ago, Cohn et al. (2001) appraised a sacred cow in economics education—the graph—and found much evidence of proliferation and status but no evidence of value added to instruction. They found that popular modern textbooks contain 200 to 400 graphs, compared to about one-tenth that number in early 20th century texts. Their experiments, however, revealed the graphical approach to be no more effective than verbal instruction alone. In one experiment, verbal instruction was actually *more* effective.

Such findings reinforced my conviction that students have difficulty seeing how each new graph on the next textbook page relates to the previous graph, and how they all interact to influence economic system performance. Prompted by the Cohn findings, I began developing another method for teaching macroeconomics to undergraduates. Called the *feedback method*, it utilizes the diagramming and simulation tools of system dynamics modeling without heavy reliance on static graphs. The instructional goal of the feedback method is to make economic dynamics accessible to students who lack the mathematical training normally considered a prerequisite for such access.

1. The Research Question

Since 2002, successive versions of the feedback method have been used in a distance learning course for undergraduates at a college in the United States. Initial assessment efforts were informal and anecdotal because so much effort was going into development. Over the past three years, however, four experiments have gauged the impact of the feedback method on student preference and performance when studying dynamics in a market economy. The motivating research question has been: ***Does the feedback method improve learning of macroeconomics?*** We will preview the research results relating to that question, but first we compare the feedback method with conventional methods of teaching macroeconomics.

2. Conventional Methods

A decade ago, when US college and university students attended class for an hour of economics instruction, they could expect about forty-eight minutes' worth of lecture and twelve minutes of activities designed to engage them actively in the learning process (Becker and Watts, 1998). Perhaps such an imbalance no longer exists, but habits change slowly. Most lectures involve presentation of economic models in the form of graphs or equations, with graphs the dominant format in undergraduate courses (Kennedy 2000). As noted above, most modern textbooks reinforce the typical instructor's emphasis on graphical analysis (Cohn et al. 2001).

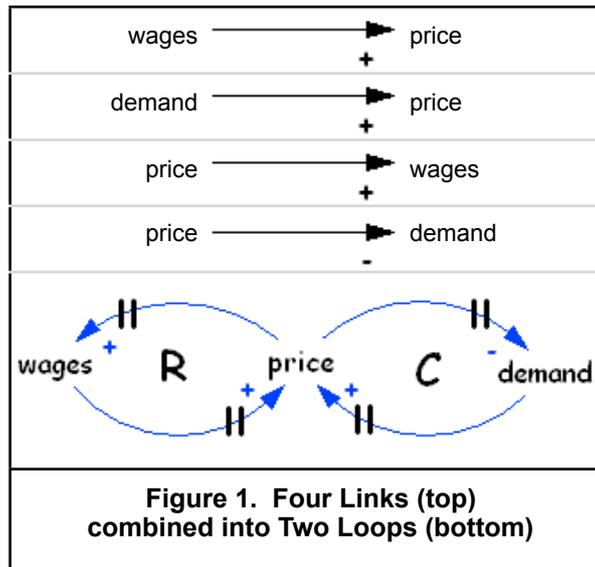
While content and context vary, the dominant type of graph displays static relationships (e.g., supply, demand, and price) in equilibrium. Change is demonstrated in graphs by comparing two equilibrium conditions before and after an exogenous shock to one of the curves on the graph. There is usually no mention of the time that might be required for such change to take place. Indeed, the very concept of dynamics—the *transition process* from one equilibrium condition to another *over some time period*—is missing in graphical comparative statics. Nevertheless, for at least a century, economists engaged in “chalk-and-talk” have shifted supply and demand curves and traced price movements, in a sincere effort to give students a visual impression of dynamics. Today, using software animation tools, instructors can make static graph curves “move” from one equilibrium point to another, *as if* the curves were responding to market forces inside the graph. Point-and-click may replace chalk-and-talk, but the implicit message is the same: finding the new equilibrium position is more important than thinking about the transition process. Colander (1991, pp. 105-106) disagrees with that message and emphasizes that any “...final equilibrium depends on the process of getting there.” He demonstrates that the workhorse graph in modern textbooks—the aggregate supply and demand (AS/AD) model—is “confusing and logically flawed, ... a crutch ... that encourages students to understand incorrectly how aggregate disequilibrium forces operate [and it should] ... never [have become] the central focus of what is taught to undergraduates.”

Reliance on static graphs in an effort to teach dynamics to undergraduates might be justified if the only alternative were differential equations, generally considered beyond the grasp of the average undergraduate in a principles course. However, not long after the Cohn findings raised questions about the efficacy of graphical instruction, another alternative was under development.

3. The Feedback Method

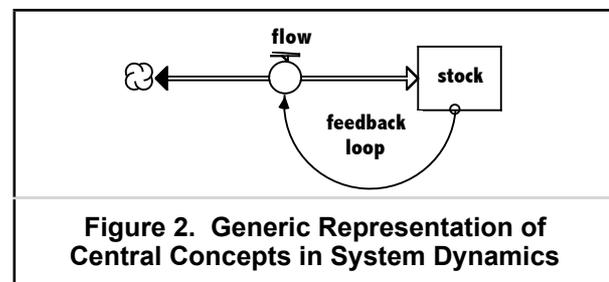
The feedback method has been developed over the past five years to teach macroeconomic dynamics without excessive reliance on static graphs or equation manipulation. Utilizing the diagramming and simulation tools of system dynamics modeling, the feedback method enables students to learn dynamics before they learn calculus. Even students without an aptitude for math are able to study dynamic behavior in a market economy.

The details of the feedback method are discussed throughout the papers and in the documentation. Here, the instructional strategy can be described simply. Initially, students consider and discuss hypotheses implicit in dozens of paired cause-and-effect links, such as the four word-and-arrow diagrams in Figure 1. At appropriate stages, the links are combined into loops, such as the two intersecting loops at the bottom of the figure. Students learn, for example, that loop R (the familiar wage-price spiral hypothesis) is a reinforcing loop that “feeds on itself,” while loop C is a counteracting loop that “seeks balance” (in this case between price and demand). As more links are studied and the loops take shape, students are virtually engaged in building a conceptual model of the economy. The development does not occur randomly, however, but is guided by the underlying system dynamics model already built. The details of the model’s 500 equations are not foisted on undergraduates; instead, the students engage the user interface, an interactive learning environment where they can experiment with the model economy.



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Figure 2 displays the central concepts in system dynamics—stocks, flows, and feedback loops—which are also the conceptual building blocks for the feedback method. A *stock* is an accumulation of material or information. A net *flow* is the rate of change in a stock. The *feedback loop* transmits information about the state of the system from the stock to the decision rules that govern the flow, which then updates the level of the stock (Sterman, 2000).



An overview of the stock-and-flow structure of *MacroLab*—the underlying system dynamics model for the feedback method—is displayed in Figure 3, page eight. If all the lower level submodels were displayed at once, the picture would be too complex for most non-specialists to interpret. Feedback loop diagrams (e.g., Figure 1) are simplified representations of underlying stock-and-flow models. When working with stock-and-flow models of complex systems such as an economy, the relative simplicity of the feedback loop often makes it a more useful tool for *communicating* with undergraduates about the model.

The system dynamics foundation of the feedback method was laid by expert modelers who studied the US economy over the past thirty years, including J. Forrester (1968, 1976, 1979, 1980), Mass (1975, 1980), Low (1980), N. Forrester (1982), Sterman (1985, 2000), and Radzicki (1993). The roots of the feedback method are not confined to system dynamics, however. Other fertile ground includes economics education research, traditional economic thought and standard textbooks, and cognitive psychology.

The Cohn article, of course, was the catalyst, but it reinforced earlier signals that the economics educational experience was less than stellar for many undergraduates. Walstad (2001) had reported experiments testing the four-decade-old Stigler (1963) hypothesis that, five years out of college, students with and without a “conventional” one-year economics course would display little difference in economics knowledge and understanding. Walstad (p. 289) concluded that “...the economics instruction that students receive at the university level seems to have little effect on what they know about basic economics when they graduate from a university or afterward...[The Stigler] hypothesis and its implied criticism of principles instruction cannot be dismissed.”

The feedback method is also tied to an important thread of feedback *thinking* in the intellectual history of economics (Richardson 1991), a topic addressed in the first paper. Despite that tradition, principles textbooks rarely mention feedback explicitly. Yet, the concept can be inferred from textbook explanations of the spending “multiplier” effect in the context of the familiar circular flow diagram of production, sales, and income. The feedback method improves on the circular flow model by adding time as an explicit influence, and it emphasizes the self-regulating role of counteracting feedback loops in a market economy.

The feedback method is a structural explanation of economic behavior, but it also aims to provide an improved *learning structure* for students, what cognitive psychologists call mental models—“inventions of the mind that represent, organize, and restructure domain-specific knowledge” (Seel, 2001). The role of mental models in shaping perceptions of external systems has long been emphasized by system dynamics computer modelers such as Forrester (1971), Meadows et al., (1974), Senge (1990), Morecroft & Sterman (1994), and Doyle et al. (2000). Yet, Doyle and others emphasize the limited capacity of persons to form accurate perceptions of the structure of *dynamic* systems and make accurate predictions of the behavior of such systems. In the context of teaching about complex dynamic systems such as an economy, therefore, visual aids that clarify *processes* of change over time may facilitate desired mental model changes. Central to the feedback method are loop diagrams that reveal the *structure* of an economy, accompanied by a user-friendly computerized version that can simulate the *behavior* of that structure.

The first paper in this thesis, **Feedback Loops in the Macro Instructor’s Toolkit**, describes the use of feedback loops as an instructional tool and illustrates one way of introducing the feedback method in a macroeconomics course.

4. Preview of Research Design and Results

Does the feedback method improve learning of macroeconomics? That question has generated several hypotheses for testing. The hypotheses can be grouped under two broad headings: student preference and student performance. The significance of assessing performance is self-evident, but the relevance of preference may be less obvious. In the second paper, we discuss the connection between the two, a premise supported by Nowaczyk et al. (1998), Sankaran et al. (2000), Terry (2001), and Stevens et al. (2004), among many others.

Four experiments have been conducted, involving 288 student volunteers from community colleges in Virginia and high schools in Massachusetts and Oregon. The smallest group was 37 in experiment #2, and the largest was 117 in experiment #4. The incentive to volunteer was the opportunity to earn “extra credit” in the course. The first two experiments focused on student preferences for teaching and learning dynamic relationships in an economy, while experiments #3 and #4 addressed the performance issue.

The second paper, **Student Preferences when *Explaining Dynamics***, discusses a study in which students were assigned hypothetical roles as tutors to a mythical “Aunt Sally,” who had a solid, well-rounded (but non-technical) education. Aunt Sally had four questions about the economy, and the student-tutors had to choose a teaching tool to supplement a verbal explanation.¹ In each case, the choice was between conventional tools (equations and static graphs) or alternative tools (stock-and-flow diagrams and feedback loop diagrams). Choices were registered by answering a questionnaire. For each of the four questions, student preference was defined as the selection of a teaching tool—either a conventional tool or a system dynamics-based tool. In response to the questions, the four tasks were:

1. Explain the relationship between production, sales, and inventories.
2. Explain the relationship between aggregate production, income, and sales.
3. Explain the relationship between disposable income, saving, and consumption.
4. Explain the sticky price theory of business cycles.

In each of the first two tasks, the “conventional” tool was an equation, while the alternative tool was a stock-and-flow diagram in task #1 and a feedback loop diagram in task #2. The students displayed an aversion to equations. They preferred a stock-and-flow diagram and a feedback loop over equations by highly significant margins ($p < .0001$ for each task). Such a negative reaction to overtly mathematical models provides an incentive for instructors to use alternative methods in introductory courses. Historically, that incentive has led to widespread reliance on static graphs.

¹ The experiment was conducted during the first week of the course, and the students would have been unable to provide even verbal explanations without assistance. Thus, each task included sufficient information for a simple verbal explanation. The only decision the students had to make was the choice of a teaching tool to reinforce the verbal explanation to Aunt Sally.

However, in tasks three and four, graphs did not evoke the response from students that graph advocates might expect. In the third task, a graph was used to display an *equilibrium* condition in a simple static situation—arguably an ideal setting for preferring a static graph. Yet, there was no significant difference in the proportion of students choosing that graph, compared to those who selected the feedback loop ($p < .57$). In the final task, when the question clearly required communicating *dynamic* relationships, a significant majority preferred the feedback loop over an aggregate supply and demand graph displaying “shifted” curves ($p < .01$).

The third paper, **Student Preferences when Learning Dynamics**, describes another experiment designed to study preferences. It differs from the previous one in two major respects. First, instead of merely measuring “first reactions,” it documents preferences revealed after a more complete instructional session. In addition, the students participating in this experiment were in the more common role as learners rather than tutors. The students were divided into two groups, and each group received two methods of instruction (in different sequence) about business cycle dynamics. One instructional method relied on a *graph* of aggregate supply and demand (AS/AD) that is common in macroeconomics textbooks. The other method relied on system dynamics-based *feedback loops* depicting aggregate supply and demand relationships. Prior to exposure to either method, all students received the same information about the so-called “sticky price” theory of business cycles, based on DeLong (2002), Hall & Taylor (1997), and Mankiw (2002, 2004). After each instructional round, students answered several questions on a five-point Likert scale indicating how much they agreed or disagreed that the instructional method provided “clear and convincing” support for the theory. Preference was measured as the difference between the Likert scores for the two instructional methods. Regardless of the sequence of instruction, the Likert scores for the feedback method were significantly higher than the scores for the AS/AD graph ($p < .001$ and $p < .003$ for the two groups), and 89 percent of the students preferred the feedback method of instruction over the graphical AS/AD model.

The experiment described in the fourth paper—**Do Stock and Flow Feedback Diagrams Promote Learning in Macroeconomics?**—is similar to the Cohn study. Two groups of students received narrative instruction about gross domestic product (GDP), but one of the two groups also received a supplemental visual aid. Instead of a graph, the visual aid was a stock-and-flow feedback diagram. Pre- and post-tests were administered, and “improvement” in the test score was the performance measure. Two measures of improvement were utilized, one being a straightforward calculation of the percentage of students in each group with post-test scores higher than pre-test scores. The second indicator of improvement—the average normalized percentage gain—measured how much of the gap between the pre-test score and a perfect score was closed when the post-test was taken after the instruction. By both measures of improvement, the group having access to the stock-and-flow diagram outperformed the group having only textual instruction. The results were significant at the .10 level of confidence, based on an analysis of the standardized difference in mean improvement scores.

The final paper, **Teaching Business Cycle Dynamics: A Comparison of Graphs and Loops**, describes a direct comparison of the efficacy of graphs and feedback loops as teaching tools. Students were divided into two groups and each received the same written narrative information about the sticky price theory of business cycles. Then each group received instruction designed to supplement the narrative background information. The instruction for one group utilized a graph—the AS/AD model—while the other group studied the interaction of two feedback loops involving aggregate supply and demand. A post-test was administered, and the questions were designed to probe the students’ understanding of the structure and behavior of their “model economy.” The group using feedback loops had a significantly higher mean performance score than the group using the AS/AD graph ($p < .03$).

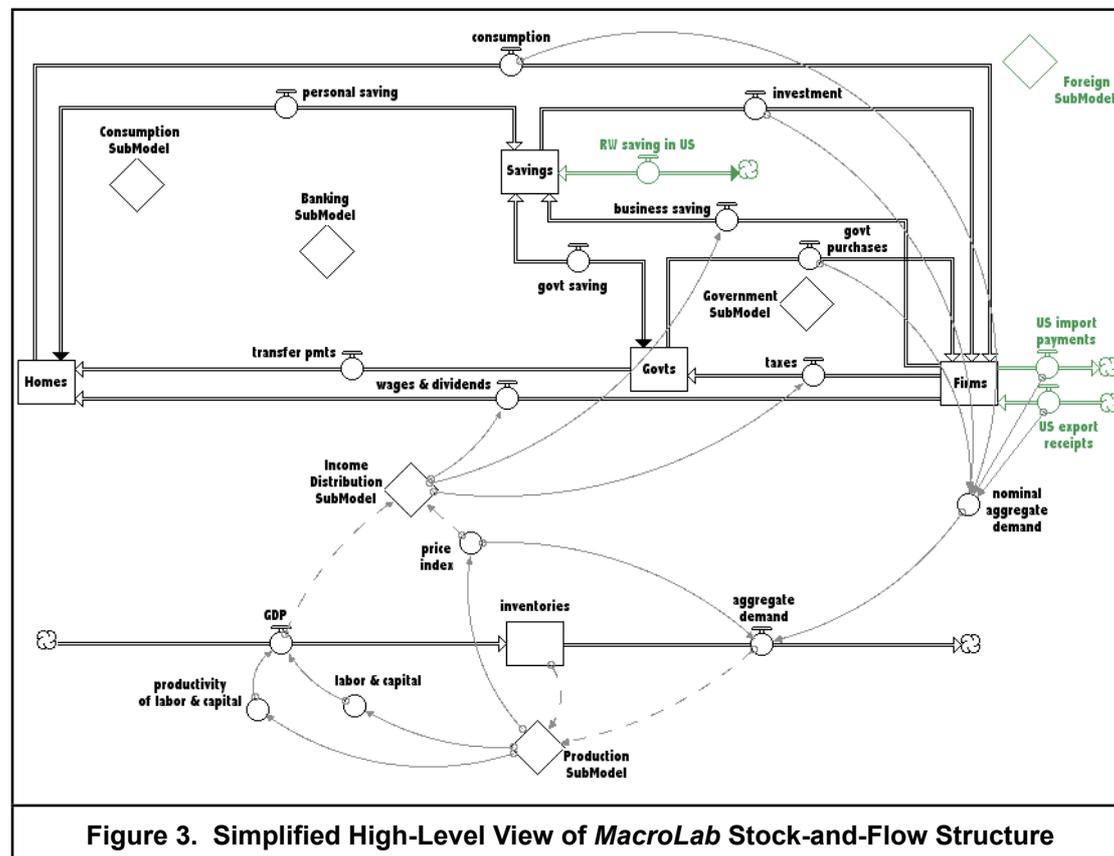
5. *MacroLab*: The Model and the Interactive Learning Environment

Each simple system dynamics model used in the experiments described above had a specific pedagogical purpose. Those simple models can be considered a sample from the full model of the US economy on which the feedback method is based. That model, consisting of about 300 distinct equations (plus another 200 equations for the foreign sector clone) is documented in the first section following the papers. Exploring the stock-and-flow structure of such a large model would be too much to expect of most undergraduates. That is one reason for using the simplified feedback loop approach. The students do get to “test drive” the model economy, however, even if they do not get to look under the hood. An extensive user interface has been developed in the form of an interactive learning environment (ILE), and the second documentation section is an introductory user guide. Together, the model and the ILE are called *MacroLab*.

The Model. Figure 3 displays a simplified, high-level view of the stock-and-flow structure of the main model. For clarity, the only information links shown are those that connect the model’s *real* sector (bottom) with its *nominal* sector (top), also referred to as the “supply side” and “demand side,” respectively. (An inadvertent omission from the diagram is the link from the capital acquisition decision process inside the production submodel to the investment flow on the nominal side.) Nominal dollars flow through the demand sector, while real quantities flow through the supply side. In the middle of the diagram, part of the nominal income generated by the supply side is divided among households, governments, and businesses on the demand side. On the far right, the nominal aggregate demand is the sum of demand-side spending by households, governments, and businesses, plus net exports, and that nominal quantity is converted to real aggregate demand on the supply side.

The diamond-shaped icons are linked to submodels for production decisions (e.g., labor employment, capital acquisition, and pricing), income distribution (to households, government, and business saving), consumption, government, banking, and the foreign sector. The documentation for each submodel includes a list of equations, a diagram of the stock-and-flow structure, and a feedback loop diagram. In

addition, various structure-behavior validation tests are described.² The documentation also includes numerous tests of the model's conformance with textbook reference behavior patterns drawn from Mankiw (2007) and McConnell/Brue (2005), two very popular textbooks in the US market. After each comparison of *MacroLab's* behavior with a textbook reference behavior pattern, a structural explanation for the model's behavior is provided.



MacroLab is a teaching model, not a forecasting model. Therefore, comparatively less time has been spent fine-tuning parameter estimates than has been devoted to developing structural relationships within the model. Nevertheless, even though tracking the actual US economy or forecasting future developments is not the purpose of the model, one would hope that its structure generates behavior that is reasonably consistent with behavior actually observed in the economy. To the extent that it does so, the model's credibility among students should be higher and its instructional utility may also be higher. Therefore, one reference behavior pattern test was a comparison of *MacroLab's* simulated behavior of US GDP with actual historical patterns over several five-year periods. For each forecast period, the model's stocks were initialized with their historical values at the beginning of the simulation period, and then the model's equations took over. The results in Figure 16 of the model documentation section display a pattern of tracking actual GDP that is at least as credible as the third-party forecasts also shown in that figure.

² The submodels are included on the CD provided with this document, and each has a series of simulation experiment options for users to explore.

The Interactive Learning Environment. For the five-year forecast exercise, *MacroLab* had to be running in *historic* mode. At the user interface level of the model—the location of the interactive learning environment (ILE)—users can alternatively select *experimental* mode for the model. The primary difference between the two modes is the initial value for each of the stocks in the model. That is just one of dozens of options available to *MacroLab* users on the Experimental Lab page of the ILE (Figure 4).

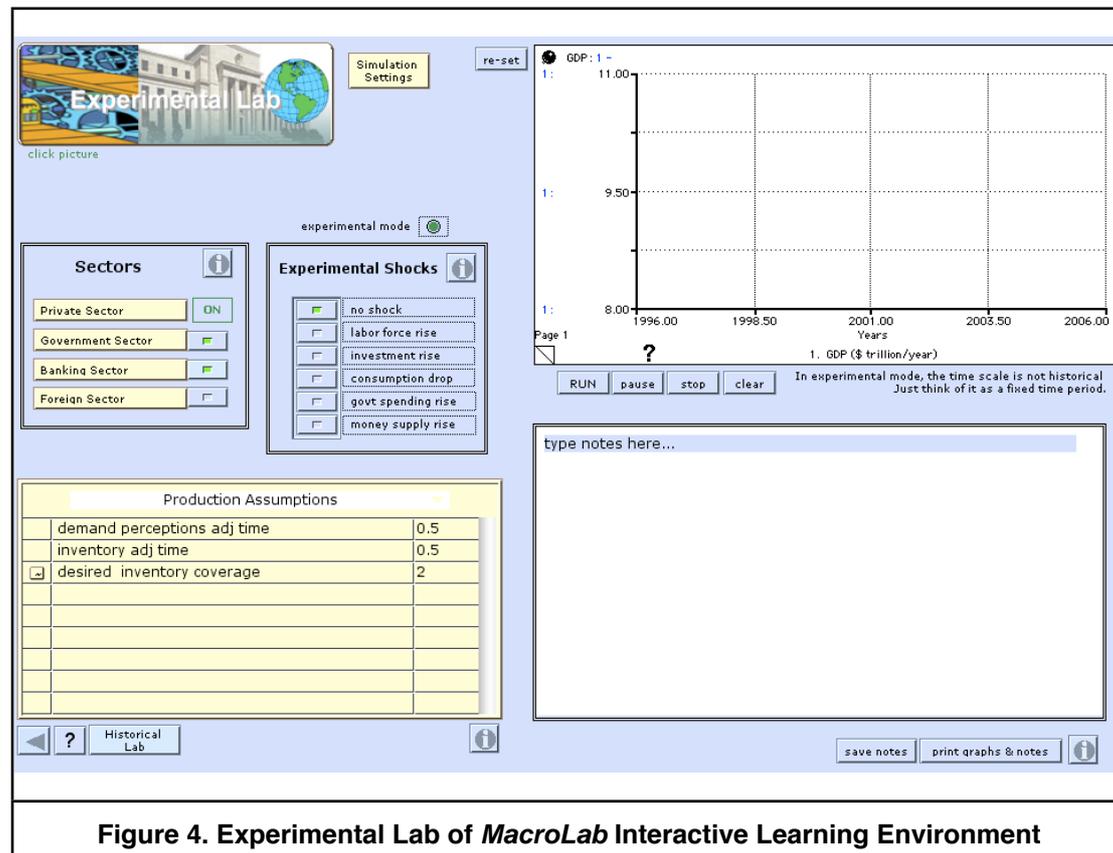


Figure 4. Experimental Lab of *MacroLab* Interactive Learning Environment

The user can activate different sectors of the model economy (e.g., government, banking, and foreign sectors), shock the model economy with sudden contractionary or expansionary forces (investment rise, consumption drop, money supply rise, etc.), and use a pull-down menu to experiment with various parameter assumptions affecting production, pricing, labor, capital, banking, fiscal policy, monetary policy, trade policy, and population and productivity growth assumptions. In addition, each sector of the model is explored in detail on a separate page in the ILE. Users can activate slide show graphics that build annotated feedback loop diagrams of each sector. Moreover, the story-telling feature of the *STELLA* software³ enables interested users to drill down to that level and get additional annotated slide shows of each submodel in its stock-and-flow format. Future versions of *MacroLab* designed for intermediate and graduate courses will provide more extensive

³ *STELLA* is a registered trademark of isee systems, inc. (www.iseesystems.com).

opportunities for exploring and evaluating both the stock-and-flow structure and the underlying equations.

While users are free to explore the ILE on their own, the feedback method of teaching macroeconomics includes specific assignments designed to facilitate student recognition of the relationship between the structure of the model and the behavior of the model. For example, one assignment requires students to study a counteracting feedback loop connecting demand, inventories, and price, with special attention given to the delay structure in that loop that affects how quickly prices adjust to perceived changes in supply/demand conditions. Students would, for example, develop and discuss a hypothesis about the effect of “sticky” prices on changes in demand and, ultimately, the employment of labor. Then the students would do a simulation experiment (e.g., shock the money supply under different price adjustment time assumptions) to test their hypotheses. Students are continuously reminded that each link in a loop represents a *hypothesis* about behavioral relationships. A particular strength of the feedback method is that it makes clear to students how theories are constructed and tested.

6. Summary

The feedback method has been developed to address two problems arising from graphical representation of economic structure and behavior. First, students seem to have trouble interpreting static graphs that are used to illustrate dynamics. Second, to use Colander’s words, the AS/AD graph can be “understood incorrectly” and students can develop misperceptions about disequilibrium economics. The assessment research results summarized in this chapter suggest that students may instinctively prefer working with feedback loop diagrams, compared to graphs. Moreover, the feedback diagrams seem to help students develop a better sense of dynamics than they get from graphs. Of course, readers will want to study the details of the experiments before reaching firm conclusions.⁴

⁴ Each paper is intended for journal publication and, as such, is prepared as a stand-alone document. Therefore, as readers move from one paper to the next, they will encounter some repetition in literature review and feedback method explanation.

References

- Becker, W. & Watts, M. (1998). *Teaching Economics to Undergraduates: An Alternative to Chalk and Talk*. Northampton, MA: Edward Elgar.
- Boulding, K. E. (1969). Economic Education: The Stepchild Too Is Father of the Man. *The Journal of Economic Education*, 1(1), 7-11.
- Cohn, E. S., Cohn, S., Balch, D., & Bradley, J. (2001). Do Graphs Promote Learning in Principles of Economics? *Journal of Economic Education*, Fall, 299-310.
- Colander, D. C. (1991). *Why Aren't Economists as Important as Garbagemen? Essays on the State of Economics*. Armonk, NY: M.E. Sharpe, Inc.
- _____ (1995). The Stories We Tell: A Reconsideration of AS/AD Analysis. *The Journal of Economic Perspectives*, 9(3), 169-188.
- Davies, P. & Johnston, C. (2003). Editorial. *International Review of Economics Education*, 1(1).
- DeLong, J. B. (2002). *Macroeconomics* (International ed.). New York: McGraw-Hill Irwin.
- Doyle, J. K., Ford, D. N., Radzicki, M. J., & Trees, W. S. (2000). Mental Models of Dynamic Systems. *Working Papers, Department of Social Science and Policy Studies, Worcester Polytechnic Institute*, 27.
- Forrester, J. W. (1968). Market Growth as Influenced by Capital Investment. *Industrial Management Review* (now *Sloan Management Review*), 9(2), 83-105.
- _____ (1971). Counterintuitive Behavior of Social Systems. *Collected Papers of J.W. Forrester*. Cambridge, MA: Wright-Allen Press.
- _____ (1976). Business Structure, Economic Cycles, and National Policy. *Futures*, June.
- _____ (1979). An Alternative Approach to Economic Policy: Macrobehavior from Microstructure. In Kamrany & Day (Eds.), *Economic Issues of the Eighties*. Baltimore: The Johns Hopkins University Press.
- Forrester, J. W., Mass, N. J., & Ryan, C. (1980). The System Dynamics National Model: Understanding Socio-economic Behavior and Policy Alternatives. *Technology Forecasting and Social Change*, 9, 51-68.
- Forrester, N. B. (1982). *A Dynamic Synthesis of Basic Macroeconomic Theory: Implications for Stabilization Policy Analysis*. Unpublished PhD dissertation, Massachusetts Institute of Technology, Cambridge, MA.
- Hall, R. E. & Taylor, J. B. (1997). *Macroeconomics* (5th ed.). New York, NY: W.W. Norton & Company.
- Kennedy, P. E. (2000). *Macroeconomic Essentials: Understanding Economics in the News*. Cambridge MA: The MIT Press.

- Low, G. (1980). The Multiplier-Accelerator Model of Business Cycles Interpreted from a System Dynamics Perspective. In J. Randers (Ed.), *Elements of the System Dynamics Method*. Cambridge, MA: MIT Press.
- Mankiw, N. G. (2002, 2004). *Macroeconomics* (5th, 7th ed.). New York: Worth Publishers.
- _____ (2007). *Brief Principles of Macroeconomics* (4th ed.). New York: Thomson Southwestern.
- Mass, N. J. (1975). *Economic Cycles: An Analysis of Underlying Causes*. Cambridge, MA: Wright-Allen Press, Inc.
- _____ (1980). Stock and Flow Variables and the Dynamics of Supply and Demand. In J. Randers (Ed.), *Elements of the System Dynamics Method*. (pp. 95-112). Cambridge, MA: MIT Press.
- McConnell, C. R. & Brue, S. L. (2005). *Macroeconomics: Principles, Problems, and Policies* (16th ed.). New York, NY: McGraw-Hill Irwin.
- Meadows, D. L., Behrens III, W. W., Meadows, D. H., Naill, R. F., & Zahn, E. (1974). *Dynamics of Growth in a Finite World*. Cambridge, MA: Wright-Allen Press.
- Morecroft, J. D. W. & Sterman, J. D. (Eds.). (1994). *Modeling for Learning Organizations*. Portland, OR: Productivity Press.
- Nowaczyk, R. H., Patton, C., & Santos, L. T. (1998). Student Perception of Multimedia in the Undergraduate Classroom. *International Journal of Instructional Media*, 25.
- Radzicki, M. (1993). A System Dynamics Approach to Macroeconomics (Guest lecture at the Department of Information Science, University of Bergen.).
- Richardson, G. P. (1991). *Feedback Thought in Social Science and Systems Theory*. Waltham, MA: Pegasus Communications, Inc.
- Sankaran, S. R., Sankaran, D., & Bui, T. X. (2000). Effect of Student Attitude to Course Format on Learning Performance: An Empirical Study in Web v. Lecture Instruction. *Journal of Instructional Psychology*, 27(1), 66+.
- Seel, N. (2001). Epistemology, Situated Cognition, and Mental Models: Like a Bridge over Troubled Water. *Instructional Science*, 29, 403-427.
- Senge, P. M. (1990). *The Fifth Discipline: The Art and Practice of the Learning Organization*. New York: Doubleday.
- Sterman, J. D. (1985). A Behavioral Model of the Economic Long Wave. *Journal of Economic Behavior and Organization*, 6, 17-53.
- _____ (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Boston, MA: McGraw-Hill Companies.
- Stevens, T., Olivarez, A., Lan, W. Y., & Tallent-Runnels, M. K. (2004). Role of Mathematics Self-Efficacy and Motivation in Mathematics Performance across Ethnicity. *The Journal of Educational Research*, 97(4), 208+.

- Stigler, G. (1963). Elementary Economic Education. *American Economic Review*, 53:2, 653–659.
- Terry, M. (2001). Translating Learning Style Theory into University Teaching Practices: An Article Based on Kolb's Experiential Learning Model. *Journal of College Reading and Learning*, 32(1), 68+.
- Walstad, W. B. (2001). Improving Assessment in University Economics. *Journal of Economic Education*, 32(3), 281-294.
- Walstad, W. B. & Allgood, S. (1999). What Do College Seniors Know About Economics? *American Economic Review*, 89:2., 350–354.