The Feedback Method of Teaching Macroeconomics: Is it Effective?

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Abstract

The conventional method of teaching macroeconomics to undergraduates relies on static graphs, an approach with documented pedagogical problems. In contrast, the feedback method uses causal loop diagrams and interactive computer simulation models. This paper describes the feedback method and four experiments that tested its effectiveness. Two experiments examined student preferences for methods of learning macroeconomics (e.g., using static graphs or a causal loop diagram), and a significant majority preferred the feedback method. 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 causal loop diagrams displayed more understanding of business cycle dynamics than those with access to a conventional aggregate supply and demand graph. Searching for feedback structure in the economy and using computer simulation to connect structure with behavior appears to be a promising method for learning macroeconomics.

Key words: dynamics, education, feedback, macroeconomics, mental model, simulation

Nearly fifty years ago, Jay W. Forrester issued his 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 a testimony to the range of work done by others in this field. Economists Michael Radzicki and Kaoru Yamaguchi have developed complete graduate-level economics courses on a system dynamics (SD) foundation. James Lyneis took his management consulting expertise into the university classroom and developed an SD-based microeconomics course, and dozens of other economists around the world have used SD models to supplement their lectures or provide an organizing framework. In that spirit of innovation, the *feedback method* of teaching macroeconomics has been developed over the past five years. Its purpose is to enable undergraduates to discover 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. This paper begins by noting pedagogical problems with conventional reliance on static graphs to teach economic dynamics, followed by a summary of an alternative approach—the feedback method. Section three reports on four experiments designed to evaluate this new approach. The last section reflects on research needed for better understanding of the findings.

1. Problems with Static Graphs in Macroeconomics

At the undergraduate level, instructors rely almost exclusively on graphs to explain and demonstrate economic models. As Kennedy (2000, p. 2) describes,

> *Students learn to analyze economic phenomena through economic models, formalized with graphs and, at advanced levels, algebra and calculus. Much time is devoted to learning how to manipulate various graphical and algebraic models that have come to serve as an intellectual framework for economists…. At the undergraduate textbook level, the technical dimension is predominantly in the form of graphical analysis…. At advanced levels the technical dimension is dominated by algebraic formulas in which Greek letters play prominent roles.*

The magnitude of the modern instructor's reliance on graphs is suggested by Cohn et al. (2001), who found that graphs in popular textbooks outnumber graphs in early 20th century texts about ten to one and sometimes twice that ratio. A principles textbook containing 200 - 400 graphs is not uncommon. The dependence on graphs could be problematic, however, for two reasons. First, the instructional value added by graphical representation of economic behavior appears to be low. The second problem concerns the predominant graphical model of modern undergraduate macroeconomics textbooks—the aggregate supply and demand (AS/AD) model. Even if students interpret that graph correctly, they can get a misleading view of dynamic behavior in the economy.

The first issue—concerning the efficacy of graphs as a teaching tool—was highlighted by Cohn et al. (2001). Cohn and his colleagues were the first to study the learning impact of graphs in introductory economics courses. In one experiment, they found graphs to be no more effective than verbal instruction alone. Another experiment found that students in a graph-supplemented lecture actually showed *less* improvement than those in a lecture-only session. The second problem—the misperception of the economy's dynamic behavior due to a *correct* interpretation of a misleading graph—has been documented by Colander (1991, 1995). He (1991, p. 106) calls the textbook AS/AD model "confusing and logically flawed, … a crutch … that encourages students to understand incorrectly how aggregate disequilibrium forces operate." Even worse (p. 108), the adjustment process they see is "…one which is superficially satisfying to students but fundamentally wrong." He concludes (p. 105) that it should "…never [have become] the central focus of what is taught to undergraduates."

In principle, the method of graphical comparative *statics* should not be used to illustrate *dynamics*—the transition process from one equilibrium condition to another over some time period. Nevertheless, common classroom—and textbook—practice reflects an implicit assumption that graphical representation of two settled equilibrium conditions is a pedagogically useful way to engage in a discussion about the settlement process in between. For more than a century, economics instructors have used chalkboards to shift supply and demand curves and infer price movements, aiming to give students a visual impression of dynamics. In the computer age, it is common practice to use slideshow software to animate static graphs, making curves "move" from one equilibrium point to another (without any economic structural reason inherent in the slideshow software). Point-and-click may replace chalk-and-talk, but the animated static graphs may be only "superficially satisfying to students" while conveying the wrong message about the transition process between equilibria. Indeed, the implicit message is that the search for the new equilibrium condition is a more important task than tracing the transition path.

The traditional justification for the graphical approach to economic dynamics is that alternative methods require a level of mathematical sophistication that is uncommon among undergraduates. However, after Cohn raised questions about the efficacy of graphical instruction in general, one wonders whether static graphs—even when animated and even if accurately reflecting disequilibrium forces—can foster the temporal reasoning skills necessary for grasping dynamics. The Colander critique (1991, p. 109) focuses on the misuse of a static graph to explain dynamic phenomena and emphasizes that any "… final equilibrium depends on the process of getting there" (e.g., the supply response to expectations of changing demand, which sets in motion a feedback process that affects actual and expected demand in the future).[1] Colander's criticism addresses a weakness in the AS/AD model that is the very strength of the feedback method, which uses causal loop diagramming and computer simulation to demonstrate how behavior emerges from structure.[2]

2. The Feedback Method

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).[3] An overview of the stock-and-flow structure of *MacroLab*—the underlying system dynamics model for the feedback method—is displayed in Figure 1.

MacroLab consists of about 300 US sector equations, plus about 200 more for the foreign sector.[4] The diamond-shaped icons (*STELLA*[5] software symbols for decision processes) are linked to six submodels—production, income distribution, consumption, government, banking, and foreign. The submodels endogenously govern the employment of labor, acquisition of capital, pricing decisions, income distribution, consumer spending and saving, money supply and interest rates, monetary policy, and government spending. It is at the submodel level that agents' decision-making occurs and that most counteracting feedback loops are visible. The high-level view in Figure 1 emphasizes the reinforcing feedback mechanism at work when real production (GDP, bottom-left in the diagram) generates nominal income (middle) that—some time later—influences nominal spending (top-right) and real aggregate demand (bottom-right).

This "simplified" view—lacking not only submodel detail but also many high-level information feedback loops that have been omitted for clarity in Figure 1—would not be considered simple at first glance by those lacking experience with such diagrams. Therefore, the students study the development of this high-level stock-and-flow structure step-by-step, and later they are expected to "see" how this structure is translated into a corresponding high-level causal loop diagram. When the stock-and-flow model evolves to a degree of complexity that is inappropriate for students in an introductory course, causal loop diagrams become more effective for communicating the underlying stock-and-flow structure. The submodels are studied almost exclusively with causal loop diagrams, with students reminded that every feedback loop contains at least one (material or information) stock and that delays associated with stock accumulations along feedback loops contribute to the dynamic behavior of the system.[6] Assignments often require students to explain how a particular delay along a specific feedback loop contributes to behaviors observed during simulation experiments. It would be unrealistic to expect them to make correct inferences about complex system behavior from structural investigation alone, despite frequent reminders that the characteristic behavior of a dynamic system is due to the endogenous interaction of stocks and flows embedded in a feedback loop structure. Thus, the combination of studying both model structure and simulated behavior is critically important for developing students' intuition about a system as complex as a national economy.

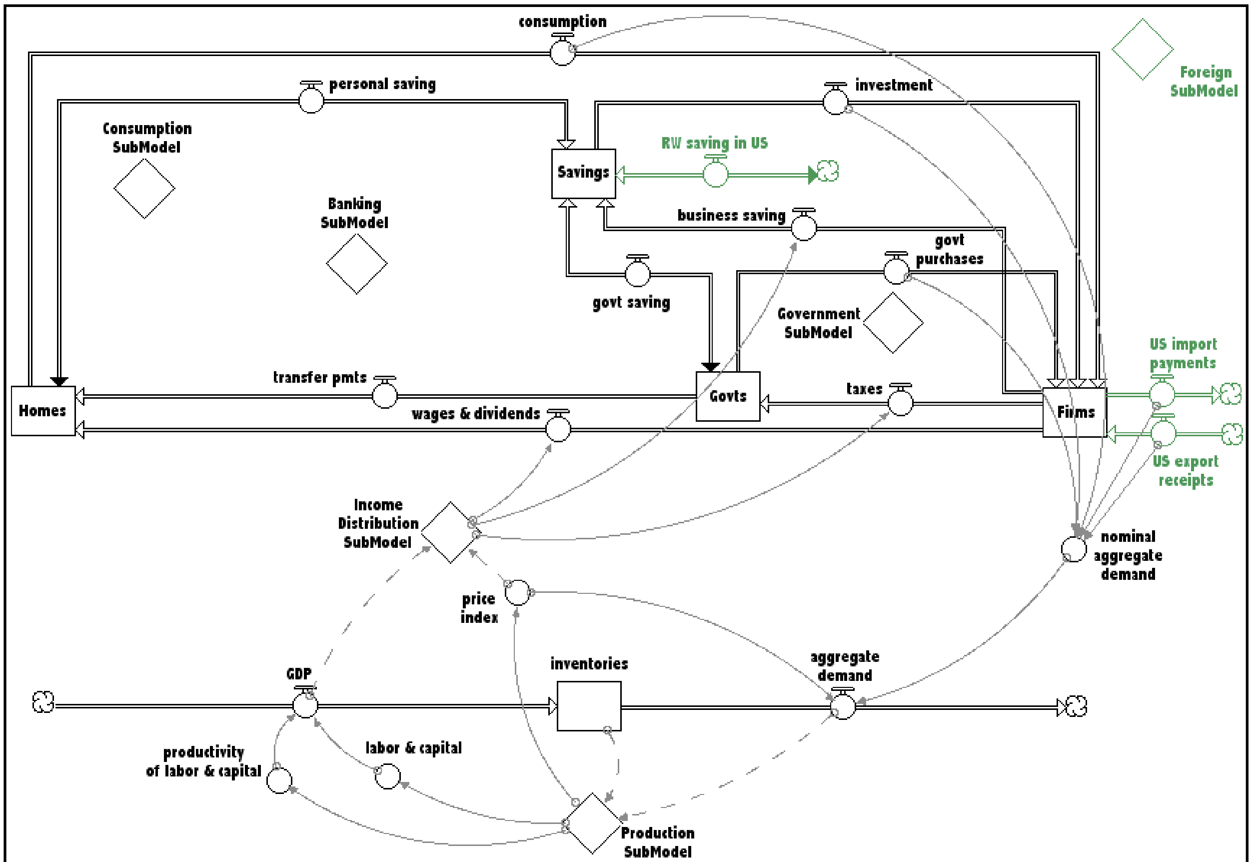


Figure 1. Simplified High-Level View of *MacroLab* Stock-and-Flow Structure

The Feedback Perspective. A useful introduction of the students to the feedback perspective is provided by an excerpt from the history of economic thought.[7] In the late 19th century, Leon Walras and Alfred Marshall debated the direction of causality between price and quantity (demanded or supplied). Oversimplifying, we could say that Walras considered price the *independent* variable while Marshall considered price the *dependent* variable (Morgan 1990). Resolution of that argument had implications for specification of early econometric models and also for the labeling of the horizontal and vertical axes in early graphical representations of demand curves. A brief paragraph outlining the views of Walras and Marshall is presented to students after they learn to draw causal links in the author's principles course. The students' assignment is to translate the viewpoints into causal link hypotheses and debate the relative merits of the two positions. Most students have no trouble writing the hypotheses displayed in Figure 2.

	independent variable	type of effect	dependent variable
The Marshall Hypothesis	supply	→ -	price
	demand	→ +	price
The Walras Hypothesis	price	→ +	supply
	price	→ -	demand

Figure 2. Competing Hypotheses about Supply, Demand, and Price

The dispute reflects a conspicuous disregard for *time* as a relevant issue, at least in this context.[8] Viewed over time with the aid of two counteracting feedback loops (a later assignment, after the students learn to combine links into loops) the apparent contradiction of the perspectives can be reconciled. When the consolidated hypotheses are displayed in Figure 3, with cross marks **||** indicating a delayed effect, the distinction between independent and dependent variable loses meaning.

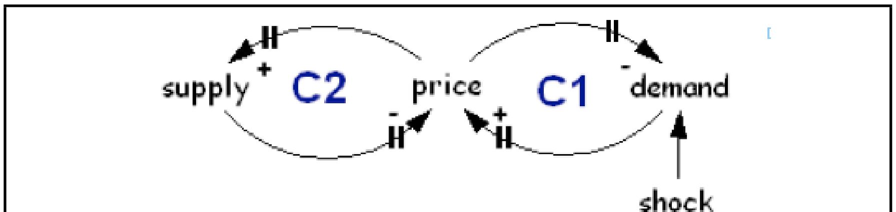


Figure 3. Feedback Loop Version of the Walras and Marshall Hypotheses

The students learn that a causal loop diagram is associated with a stock-and-flow structure in a computer model that can be simulated. Figure 4 shows the simulated behavior arising from the hypothesized feedback structure in Figure 3, after an exogenous shock to demand. Throughout the course, the students have many assignments requiring them to explain behavior (e.g., Figure 4) in terms of structure (e.g., Figure 3). In this example, we assume that a permanent exogenous shock boosts demand. After suppliers take time to evaluate the reliability of the signal that demand has increased, price would rise. The rising price would, in turn, put downward pressure on demand, the full effect of which would develop over time. Meanwhile, suppliers respond to the rising price by stepping up production, but it takes time to organize the requisite factors of production. When supply eventually responds, that puts downward pressure on prices, but with a delay. Students should learn to anticipate cyclical behavior when multiple delays exist along counteractive feedback loops. Of course, the particular damped oscillatory behavior and the amplitude and period for each curve would depend on parameter assumptions for delay times and price elasticities and could not be inferred from the causal loop diagram.

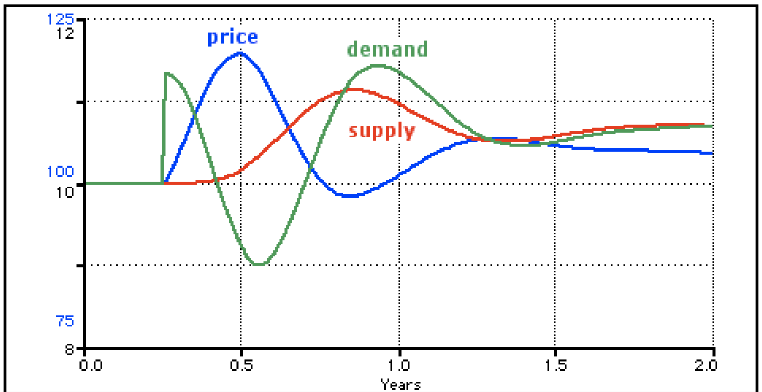


Figure 4. Simulated Behavior of Stock-and-Flow Version of Feedback Loop Structure in Figure 3

One benefit of the feedback method is that the crux of theoretical disputes can often be visualized in a simple diagram. Then simulation enables testing the implications of the feedback model. Competing theories can be tested separately or, as in this case, in combination. One might conclude, for example, that this simplified debate between Walras and Marshall reflects a difference of opinion about the relative delays that influence price, demand, and supply.

With this example as background, the instructional strategy of the feedback method is easily described. Initially, students discuss hypotheses implicit in dozens of paired cause-and-effect links, such as the four links in Figure 5. Eventually, 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 combined into loops, a model of an economy begins to develop. The development does not occur randomly, however, but is guided by assignments tied to an interactive learning environment (ILE) and its underlying system dynamics model, together known as *MacroLab*. When the students engage *MacroLab*, they can experiment with the model economy and observe simulated behavior arising from structure they have studied.

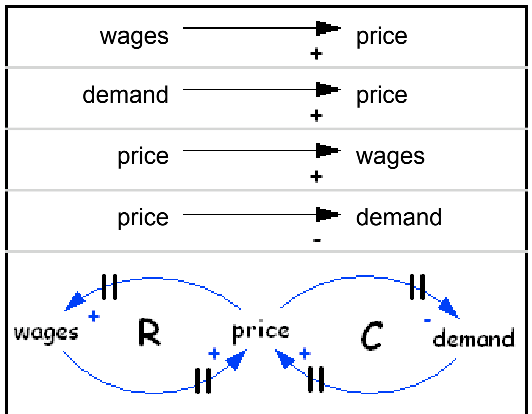


Figure 5. Four Links (top) combined into Two Loops (bottom)

While students are getting the standard textbook introduction to measurement of economic indicators during the first few weeks of the course, they are also viewing historical time series data with *MacroLab's* interface and learning to "read and write" simple links and loops. The students first practice their new skills in hypotheses-building exercises. They are required to develop *ceteris paribus* cause-and-effect hypotheses about the economic indicators they have been studying. After viewing historical data on employment and the unemployment rate, for example, each student is asked, "What might cause the level of employed labor to change?" The answer has to be expressed in a word-and-arrow diagram, and the student must write a few sentences that interpret the intended meaning of the link.

For example, the hypotheses in Figure 6 were offered by two students writing in the threaded discussion forum of their distance learning course. These two hypotheses, despite some glaring weaknesses, are among the better ones received in the first assignment. Initially, some students can say little more than "employment goes up when the economy goes up."

Student #1	*consumption* $\xrightarrow{+}$ *employed labor*
If consumers begin to increase their levels of consumption of goods and services more employees will be need to fulfill those desires. The reverse is true, if people begin to lessen their use of these services then the employees will not be needed and employment will be down, along with the demand.	
Student #2	*fuel prices* $\xrightarrow{-}$ *employed labor*
Due to the recent increase of fuel cost and the current slowing of the economy the demand for certain products causes manufacturers to increase their prices and cut production. In return this causes a decrease in manpower, which later results in layoffs.	

Figure 6. Hypotheses from Two Students

The students' hypotheses always motivate follow-up discussion aimed at clarifying misconceptions or faulty logic. After more reading and several similar assignments, the students eventually begin to grasp the *ceteris paribus* links in Figure 7. As the course develops, many other paired cause-and-effect links are identified and discussed. At appropriate stages, the links are combined into loops. The students are virtually engaged in building a conceptual macro model.

aggregate demand	$\xrightarrow{+}$	demand for labor
demand for labor	$\xrightarrow{+}$	employed labor
employed labor	$\xrightarrow{+}$	GDP
GDP	$\xrightarrow{+}$	wages
wages	$\xrightarrow{+}$	consumption
consumption	$\xrightarrow{+}$	aggregate demand

Figure 7. Causal Link Hypotheses, Set 1

The first feedback loop studied in the *MacroLab* model—R1 in Figure 8—uses the links in Figure 7. It is similar to the reinforcing loop implicit in the ubiquitous textbook circular flow diagram. For initial simplicity, all income is treated as wages, and there is no saving or investment, no government, no central bank, and no foreign trade. As more loops are added to the model, such influences are added and endogenized. Students recognize R1 as an example of a reinforcing feedback loop that "feeds on itself." They sometimes call it the "boom or bust loop" because its reinforcing effects could be either virtuous or vicious.[9]

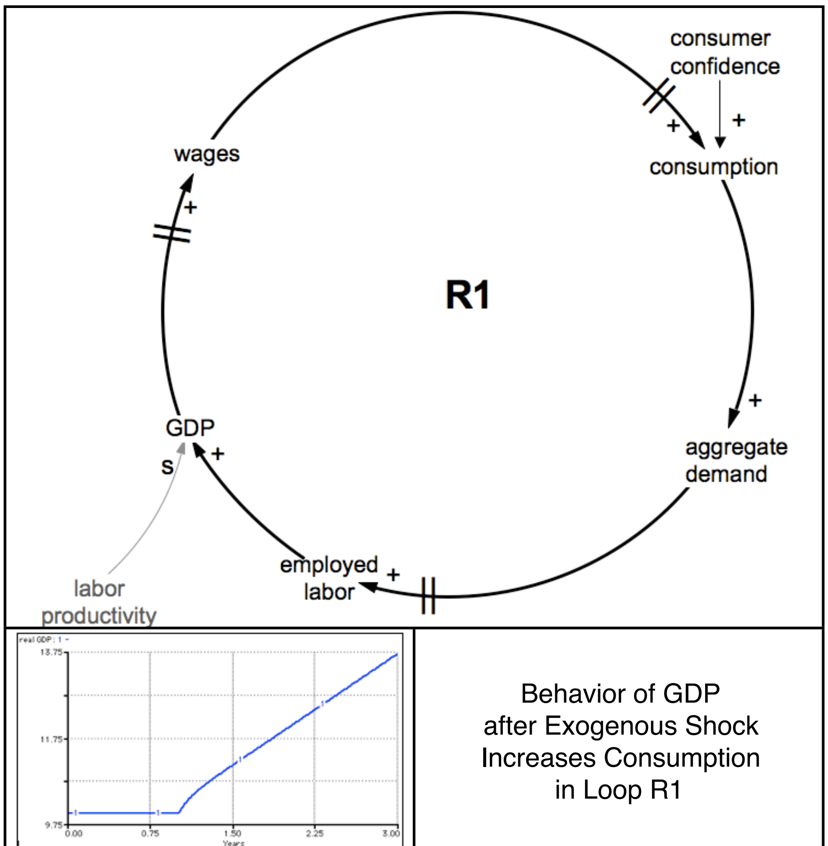


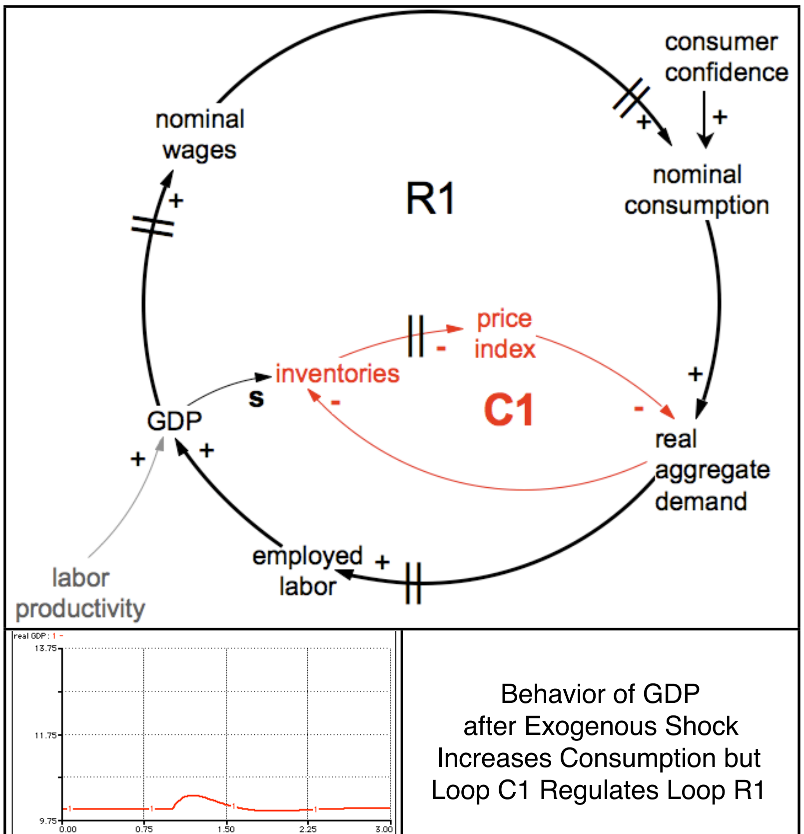
Figure 8. Simplified Main Reinforcing Loop Structure and Simulated Behavior of Associated Stocks and Flows

Figure 8 also includes the hypothesis that an exogenous rise in consumer confidence would give a boost to consumption (and aggregate demand). The significance of any consumer confidence effect is an empirical question, but the link illustrates a demand-side shock that students can grasp at an early stage in the course. Moreover, it enables an early simulation test of the behavior of the R1 loop structure, illustrated by the behavior of GDP in the small panel below the loop. In the absence of counteracting loops, the exogenous shock would cause GDP to increase without limits. A review of historical trends using the database feature of the *MacroLab* simulator, however, contradicts any expectation that a market economy grows forever (or is doomed to collapse following an adverse shock). Answering the "Why not?" question requires finding some counteracting feedback loops, and that means thinking about some new links.

We usually focus next on hypotheses that involve real aggregate demand, product prices, and inventories. The first three links in Figure 9 form the counteracting feedback loop C1 in Figure 10.[10] The increase in real aggregate demand reduces inventories, which leads eventually to price increases that slow the growth in real aggregate demand. Thus, loop C1 has the effect of counteracting the initial momentum for growth.

inventories	$\xrightarrow{-}$	price
price	$\xrightarrow{-}$	real aggregate demand
real aggregate demand	$\xrightarrow{-}$	inventories
GDP	$\xrightarrow{+}$	inventories

Figure 9. Causal Link Hypotheses for Loop C1 in Figure 10



Behavior of GDP after Exogenous Shock Increases Consumption but Loop C1 Regulates Loop R1

Figure 10. Counteracting Loop Structure and Simulated Behavior of Associated Stocks and Flows

The strategy in this opening round of feedback method instruction is straightforward. First, show the potential for continuous growth (or decline) in loop R1. Then illustrate that counteracting loops are the self-regulators in developed market economies, serving to inhibit (and sometimes reverse) the trends set in motion by loop R1. When the quantity and/or productivity of real resources increase, reinforcing loops contribute to a pattern of growth which, when sustained, is interpreted as the "trend." Departures from trend—fluctuating patterns resembling "cycles"—can occur endogenously due to counteracting loops. As new reinforcing and counteracting loops are added to the model throughout the course, students have an opportunity to assess their significance for the behavior of the model economy.

Using the *MacroLab* simulator, students conduct experiments with different parameter assumptions, such as delays along a loop. For example, they simulate the effects of different price adjustment times in loop C1. Figure 11 illustrates such a simulation experiment after the full model has been developed.

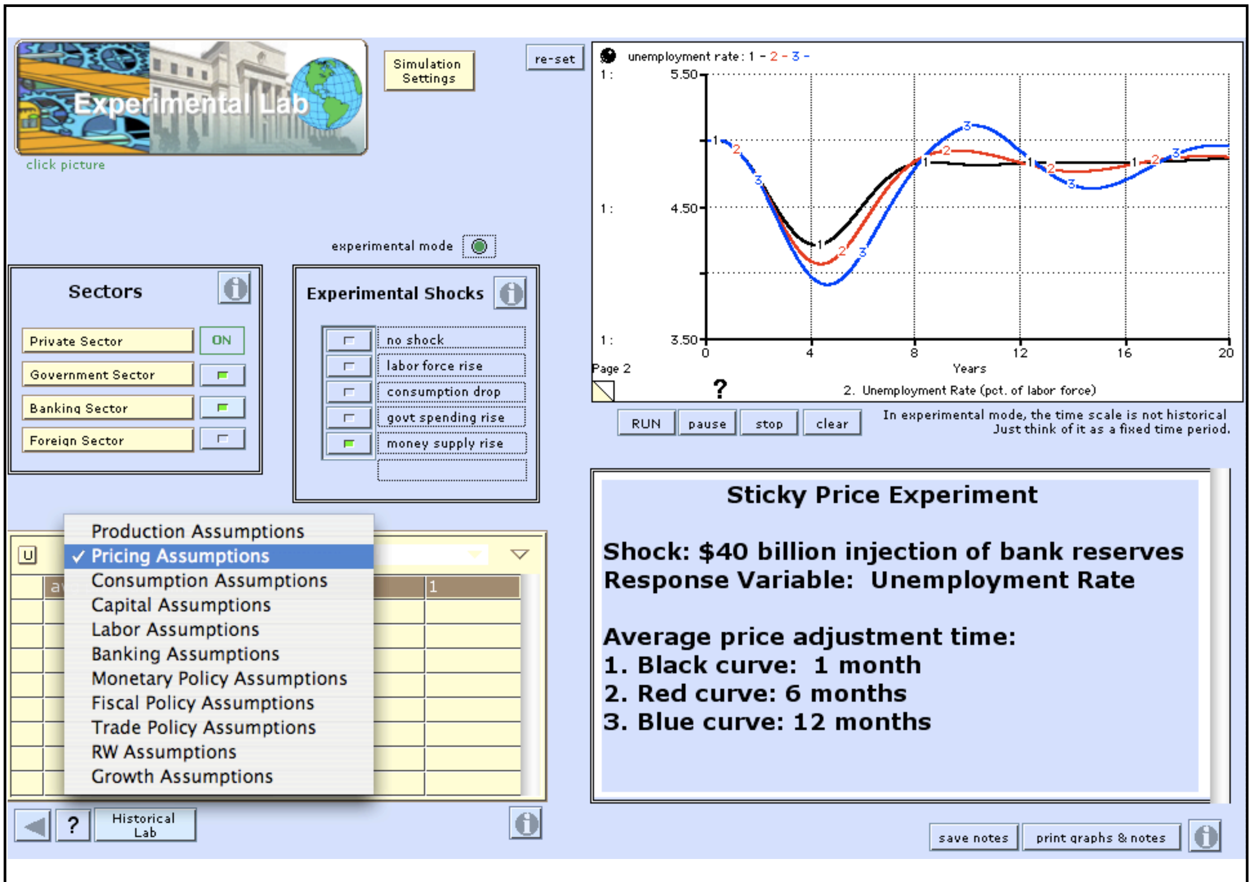


Figure 11. Experimental Lab Results of a Simulation Experiment

The graph is Figure 11 displays the endogenous response of the model to an experimental exogenous shock comparable to the central bank suddenly increasing bank reserves with a pulse injection of $40 billion.[11] The graph tracks the behavior of the unemployment rate following the shock. The purpose of this particular experiment was to see if the behavior of the model would be consistent with the so-called "sticky price theory" of business cycles. In essence, the theory predicts that long delays in price adjustments will make it harder for the counteracting loop C1 in Figure 10 to perform its self-regulating role, with the result that the economy will exhibit greater fluctuations after a shock. The results in Figure 11 are consistent with the theory—the unemployment rate stabilizes quickly when the average price adjustment time is 1 month (curve #1) and fluctuates much more when the average delay is 12 months (curve #3). Following this simulation experiment, students are required to review counteracting loop C1 and explain why a slow price adjustment weakens the loop's counteracting influence. Finally, students are exposed to empirical research suggesting that, on average, US firms wait about three months to change prices after first noticing changes in market demand conditions (Blinder, 1997).

The potential for a market economy to regulate itself does not guarantee that corrective adjustments will be timely or politically acceptable. *MacroLab* has endogenous fiscal and monetary sectors that respond to economic conditions according to hypothesized links in the model. The interface permits students to make experimental modifications to parameters and structure for the purpose of exploring, for example, how changes in government policy affect economic performance. The ability to simulate different sectors of the economy—to turn sectors ON and OFF and simulate—presents powerful learning opportunities (e.g., simulating *with* and *without* the foreign sector). The rest of the course involves exploring the "sides" of the economy—supply side and demand side—and the sectors within each side (e.g., government sector, monetary sector, foreign sector) and the sub-models within each sector (e.g., labor, capital, pricing, consumption, interest rates, income distribution, and government budgeting). In each case, the approach is similar: identify key links, connect the loops, and analyze the potential behavior of the loops. Of course, the net influence of all the loops in the system may not be at all intuitive, and that is why simulation capability adds so much to the diagramming aspect of the feedback method.

3. Assessment of the Feedback Method

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. Four experiments have been conducted, involving a total of 288 student volunteers (with sample sizes ranging from 37 to 117) in community colleges in Virginia and high schools in Massachusetts and Oregon. 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 significance of assessing performance is self-evident, but the relevance of preference may be less obvious. In short, we presume a connection between preference and performance, a premise supported by Nowaczyk et al. (1998), Sankaran et al. (2000), Terry (2001), and Stevens et al. (2004), among many others. The detailed descriptions of the design and findings of the preference and performance experiments are presented in Wheat (2007), and the summary reported here focuses on comparisons between causal loop diagramming and the AS/AD graph.

Assessment 1. In the first experiment (Wheat 2007, paper two), 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 questions about the economy, and the student-tutors had to choose a teaching tool to supplement a verbal explanation. In each case, the choice was between conventional tools (equations and static graphs) or alternative tools (stock-and-flow diagrams and causal loop diagrams). Preference was registered by answering a questionnaire.

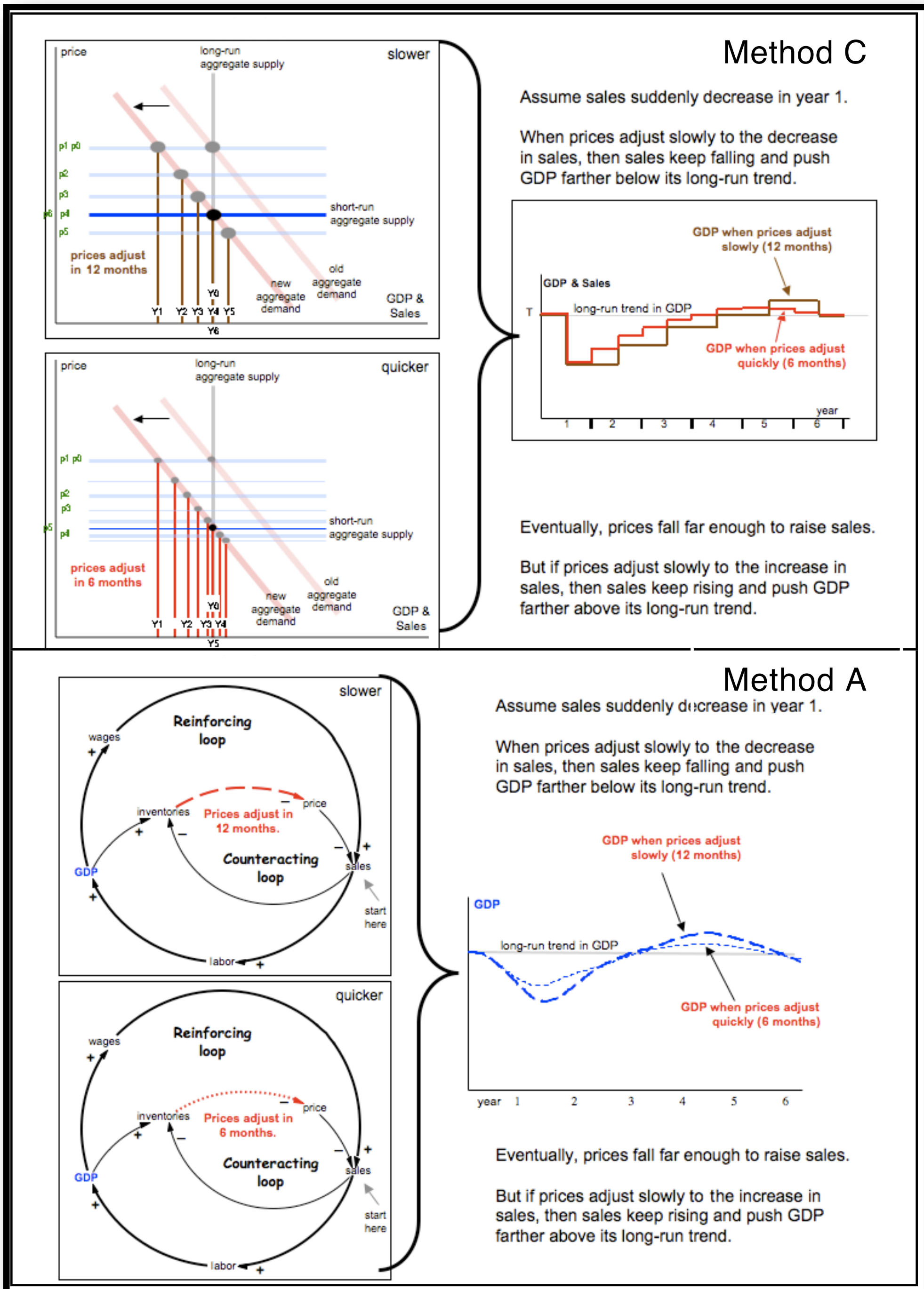


Figure 12. Diagram for Assessment 1

One task required selecting a teaching tool to help Aunt Sally understand business cycles. Since the students had no preparation for such an explanation, their instructions provided a theory and a choice of tools to help explain the theory. The students' conventional option was the AS/AD model, Method C in Figure 12, adapted from Hall & Taylor (1997, ch. 8-9), Mankiw (2002, ch. 9; 2004, ch. 20; 2007, ch. 15). The system dynamics-based teaching tool in this experiment was the causal loop diagram designated as Method A in Figure 12. The student "tutors" received these instructions:

> *Aunt Sally wants an explanation of business cycles. Suppose you believe the theory that says, "If prices adjust slowly to changes in demand, GDP will deviate more from its long-run trend." Looking at the diagram below, would you select Method C or Method A to help you explain that theory?*

A significant majority—70 percent—of the students preferred the feedback loop method. The t-value in a two-tail test of proportions was 2.86 with 45 degrees of freedom, and $p < 0.01$.

Assessment 2. The second preference experiment (Wheat 2007, paper three) was similar to the first assessment in one respect: in both experiments, the graphical instructional tool was the AS/AD model while the alternative tool was a simple causal loop diagram. However, there is an important difference between the two experiments. Instead of merely measuring first reactions to the "pictures" in Figure 12, the second experiment documented student preferences revealed after a more complete instructional session. The students were divided into two groups, and each group received *both* methods of instruction—graphs *and* feedback diagrams, in different sequence—about business cycle dynamics. 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 by comparing 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.

Assessment 3. The third experiment (Wheat 2007, paper four) 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, however, the visual aid was a stock-and-flow feedback diagram revealed in stages to accompany the narrative. Figure 13 displays the completed 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.

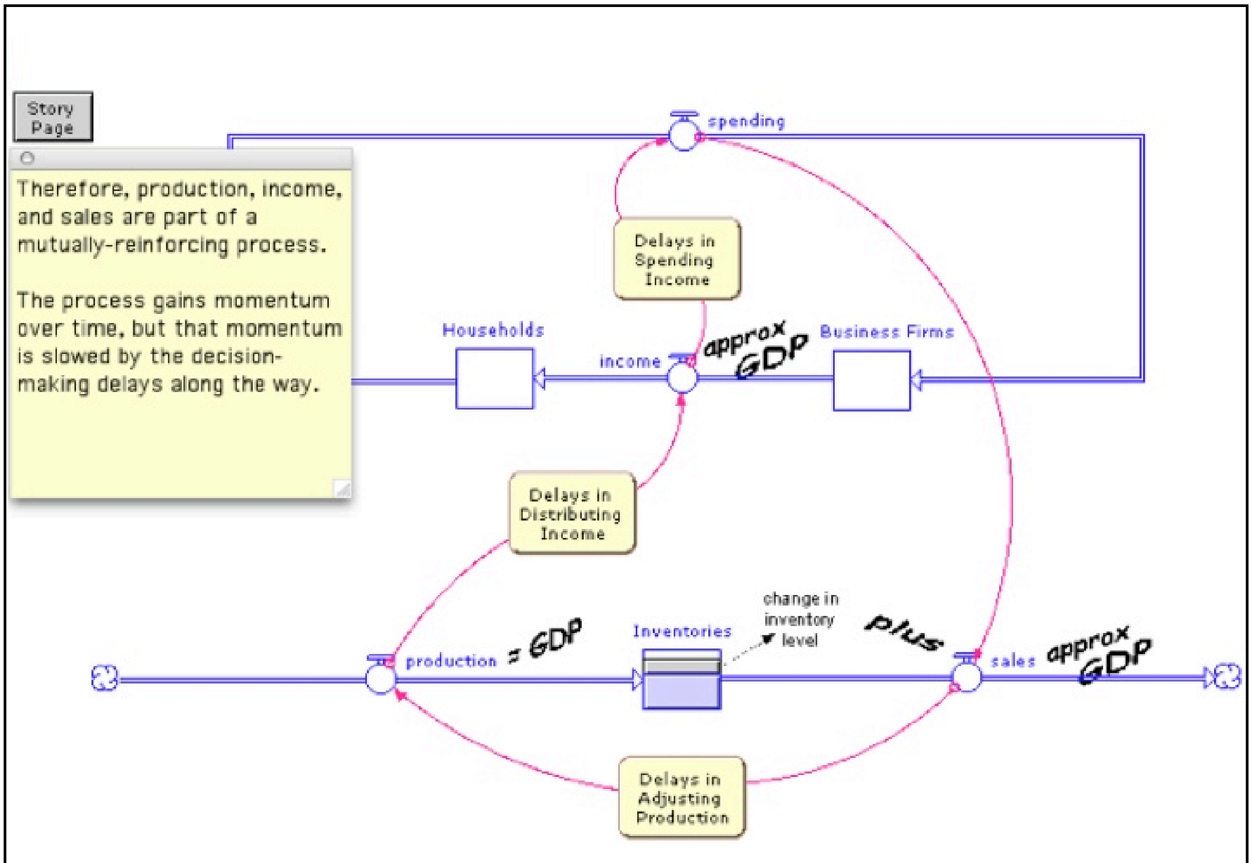


Figure 13. Completed Stock-and-Flow Structure used in Assessment 3

The control group in this experiment did not use a graph. However, given the Cohn findings that graphs did not add instructional value to mere verbal instruction, this experiment can be interpreted as an *indirect* comparison of the feedback method with the graphical method. In contrast to the Cohn experiments where the graph "picture" was not worth the proverbial thousand words, the feedback diagram appears to have added significantly to the students' learning experience.

Assessment 4. The final experiment (Wheat 2007, paper five), made 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 content of the two supplemental methods was similar to that used in an earlier experiment (Assessment 2); i.e., one method utilized the AS/AD model, while the other relied on the interaction between two feedback loops affecting aggregate supply and demand. However, the difference between Assessment 2 and Assessment 4 was that, in the latter experiment, each student group received instruction in one method only and student performance rather than preference was measured. After students completed their learning task, they answered several test questions designed to measure knowledge and understanding (Figure 14).

Question Stem	Multiple Choices			
Q1. Each year, according to the diagram, a change in	(a) sales affected prices first and GDP later.	(b) sales affected GDP first and prices later.	(c) sales affected GDP and prices at the same time.	(d) prices affected GDP first and sales later.
Q2. After the initial drop in sales, GDP	(a) rose before falling and then fell without stopping.	(b) fell and sales dropped even more before both rose.	(c) fell and then rose as soon as prices started falling.	(d) each of the above is correct. (e) none of the above is correct.
Q3. According to the diagram,	(a) a change in sales will affect GDP and prices.	(b) a change in prices will affect sales and GDP.	(c) a change in GDP will affect prices and sales.	(d) each of the above is correct. (e) none of the above is correct.
Q4. After the initial drop in sales and GDP, the fall in prices indicates that	(a) GDP was below its long-run trend.	(b) GDP was above its long-run trend.	(c) sales dropped more than GDP.	(d) sales dropped less than GDP.
Q5. Suppose sales dropped suddenly and prices adjusted slowly. The diagram used in this activity would predict the behavior in graph	(a) A	(b) B	(c) C	(d) D
	see appendix of Wheat (2007, paper 5) for diagram			
Q6. Assume sales suddenly increased, followed by a rise in GDP. If prices rose, that would indicate	(a) sales increased less than GDP.	(b) sales increased more than GDP.	(c) GDP was above its long-run trend.	(d) GDP was below its long-run trend.
Q7. Suppose each time sales changed, prices adjusted a month later instead of a year later. Then	(a) GDP and employment would rise and fall more.	(b) GDP would rise and fall more, but employment would rise and fall less.	(c) GDP would rise and fall less, but employment would rise and fall more.	(d) GDP and employment would rise and fall less.
Q8. According to the diagram, decisions about employment, production, and pricing are based on knowledge of	(a) random events.	(b) long-run trends.	(c) business conditions.	(d) equilibrium requirements.

Figure 14. Test Questions in Assessment 4 (correct answers shaded)

A requirement for the test instrument, in addition to trying to uncover a sense of dynamics, was inclusion of questions requiring more than mere factual recall. Ostensibly, Q1-

Q2 gauge students' *comprehension* (as defined by Bloom, 1956). However, both questions relate to fundamental hypotheses of the sticky price theory and, in fact, could have been recalled from memory—the *knowledge* level in Bloom's taxonomy—since the text-only version of the theory presented the "answer." Either characterization puts those two questions near the bottom of the hierarchy of cognitive skills. The next five questions (Q3-Q7) go beyond knowledge and comprehension and require various combinations of higher order cognitive skills. Q3 requires prediction (an *application* skill). Q4-Q6 require inference, which Blooms considers *analysis*, although the tasks require seeing how a total system works rather than taking it apart. These arguments aside, Q3-Q6 unquestionably require skills above and beyond factual recall or even restatement of a theory. Q7 addresses a fundamental point of the sticky price theory—quicker price adjustments restore stability sooner after a shock to the economy. A correct answer (for the right reason) would seem to require *application* of a theory.

The last question (Q8) was designed to probe student understanding of *why* the implicit economic agents in the model were generating the observed behavior. In Bloom's terms, answering Q8 was probably an exercise in *comprehension* and/or *analysis.* Assessment of the responses to Q8 is not so much a determination of "right" or "wrong" answers as it is a comparison of answers. After studying the AS/AD model, it may be "correct" to assume that searching for equilibrium *is* the motivating influence on behavior, and Q8 was included in order to see if students using that model would reach that conclusion.

For several reasons, a benchmark pre-test was not used. First, the sticky price theory was considered a sufficiently obscure topic that the subjects in the experiment (even those who had some prior economics education) would have no prior knowledge of the theory; essentially, a zero pre-test baseline was assumed for all students. Second, the learning assessment focused on understanding the structure and behavior of each method's economic model, which again was assumed to be virgin territory. The questions requiring inference and interpretation would have been meaningless out of context in a pre-test setting. Finally, pre-tests can be problematic if they heighten awareness of important concepts prior to instruction (the "pre-test effect") and, therefore, blur distinctions between the impacts of the instructional treatments.

The effectiveness of each instructional method was operationally defined in terms of accurate student responses to the post-experiment test questions. On the overall test, the group using feedback loops had a significantly higher mean performance score than the group using the AS/AD graph ($p < .03$). On the two questions (Q1-Q2) at the relatively low end of the cognitive skill requirement range, there was no significant performance difference between the two instructional methods. However, on four of the six questions requiring somewhat higher order thinking skills (Q3-Q8), the feedback loop method was significantly more effective. Particularly noteworthy were the answers on Q8, where students using the feedback loop were more likely to display a real-world perspective on business decision-making. Students using the AS/AD graphs were more likely to conclude that business managers are guided by abstract criteria (e.g., the search for equilibrium or long-run trends). This misperception is significant because it illustrates how the AS/AD model can mislead. When students focus on the choreographed movement of lines on a graph, the learning challenge becomes “seeing the dance” rather than thinking about real people making real decisions in a real economy. Students may think they know what is happening in the economy when they have learned to read the graph. In Colander’s (1991) terms, they “understand incorrectly.”

4. Conclusion

Nearly fifty years ago, educational psychologist Jerome Bruner (1960) concluded that “the most basic thing that can be said about human memory…is that unless detail is placed into a *structured pattern*, it is rapidly forgotten.” The pedagogical potential of the feedback method was suggested by Forrester’s (1994) description of system dynamics as a “…*framework* into which facts can be placed [so that] learning becomes more relevant and meaningful.”

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. In that context, students’ own explanations during the first preference experiment are revealing. When selecting the feedback diagram over the graph in Assessment 1, the phrase “describes a process” was most often used by students to explain their choice. Future research should include efforts to better understand how students form mental models of economic processes.

The assessment results summarized here and detailed in Wheat (2007) indicate that, compared to graphical representation, students prefer an approach to economic dynamics that relies on feedback representation. Moreover, feedback diagrams appear to add more instructional value than static graphics used to illustrate dynamics. The feedback method of using loop diagrams to reveal the *structure* of an economy, accompanied by a user-friendly computer model that can simulate the *behavior* of that structure, appears to be a promising method of teaching macroeconomics.

Notes

[1] On the issue of misperception of feedback, see Moxnes (1998) and Sterman (2000, chapter 1).

[2] The feedback method provides the organizing framework for the author’s macroeconomics principles course delivered via the Internet to students enrolled at Virginia Western Community College in Roanoke, Virginia, USA.

[3] Standard references for system dynamics methodology include Forrester (1968), Richardson and Pugh (1989), Ford (1999), and Sterman (2000).

[4] Model documentation is available online at https://bora.uib.no/handle/1956/2239

[5] *STELLA* is a registered trademark of isee systems, inc. (http://www.iseesystems.com)

[6] Consider Figure 10, for example. Students should learn that employed labor and inventories are delay-adjusted material stocks. In the principles course, the concept of an information stock *per se* receives less emphasis than the notion of a *delay* in decision-making as information is received and processed. Students learn, for example, that consumer spending responds gradually to accumulated information about changes in wages. Likewise, they learn that prevailing prices reflect a delayed response to the prices indicated by managerial perceptions of changing inventory conditions.

[7] Evidence of a tradition of feedback thinking among economists—albeit neglected and underutilized—is documented in Richardson (1991).

[8] Obviously, those two giants of economic intellectual history did not think merely in static terms. Marshall, for example, stressed that price elasticity of demand depended on the passage of time, and even Walras' auctioneer had to process information in a time-consuming iterative process of matching supply and demand before arriving at an equilibrium price (Pressman, 1999). After an extensive review of Marshall's work, Glassburner (1955, p. 594) concluded that Marshall believed "the economist's proper focus should be on dynamic reality rather than on static logical reasoning." In his view, Marshall intended *Principles of Economics* (1890, 1920) to be merely a simplified, "pedagogically useful" introductory text; those who consider it "evidence" of Marshall's preference for static economic analysis are both misreading and misrepresenting the Cambridge economist.

[9] Fujita (2007) provides a useful historical summary of the intellectual linkages involving the concept of "circular and cumulative causation," from Kaldor back to Myrdal, Wicksell, Veblen, and Young, with the latter influenced by Marshall and Smith. The broader tradition of both positive and negative feedback thinking among economists is documented in Mayr (1970, 1971), Cochrane and Graham (1976), and Richardson (1991).

[10] Implicit in Figure 10 is that wages and consumption are nominal quantities. Since consumption is the only component of aggregate demand in the diagram, real aggregate demand is equal to consumption divided by the price index. Not shown in this diagram is the multiplying of real wages by the price index to obtain nominal wages.

[11] With the banking submodel activated, the money supply can grow *endogenously* when banks make loans and create new deposits. In addition, an *endogenous* central bank policy sector is also activated, with the capability to conduct open market operations in response to information feedback about economic conditions (e.g., inflation and the unemployment rate) that are relevant to the central bank's monetary policy goals. Thus, the experimental *exogenous* money supply shock displayed in Figure 11 does *not* mean that the model is based on an assumption of "exogenous money." In general, the model's central bank policy responds to undesired economic conditions by changing the target federal funds rate via open market operations, which affects commercial banks' reserves and the market interest rate. The resultant change in lending—and the change in money supply via new deposits—depends on the endogenous response of banks and borrowers.

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