Endogenous Feedback Perspective on Money
in a Stock-Flow Consistent Model

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Abstract: This paper is primarily for instructors looking for additional ways to teach the endogenous view of money creation; i.e., the view that money supply responds to the economy's credit demands, in contrast to the textbook money multiplier suggestion that central banks can unilaterally adjust the monetary base to trigger desired changes in the money supply. The approach described here helps students develop a systemic feedback perspective that illuminates endogenous money in a transparent conceptual model. Then they learn to use a simulation model that illustrates endogenous money dynamics. The paper has two additional purposes with a broader audience in mind. It proposes a consensus-building definition of endogenous money to mean 'created by an endogenous feedback structure.' Also, it supports the call for post-Keynesians and institutionalists to experiment with system dynamics as a method of scientific inquiry and a tool for dynamic simulation of economic systems characterized by uncertainty, delays, nonlinearities, and feedback in structures that reflect socioeconomic and political history.

Keywords: central bank, economics education, endogenous, exogenous, feedback, macroeconomics, monetary policy, money, system dynamics model, systems thinking

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1 Introduction

Imagine this question from an economics faculty recruitment committee: "How do you teach, is money exogenous or endogenous?" A similar question crops up in a story told long ago by a Texas school-teacher-turned-politician: Lyndon Johnson. The story is about an unemployed geography teacher interviewing for a job during the Depression. The local school board members asked, "How do you teach, is the world round or flat?" Hoping to avoid an answer that might disqualify him, he replied, "I can teach it either way." (McPherson 1972, pp. 108)

You have a choice in your approach to teaching about money supply in a macroeconomy. You may even teach it both ways, to be sure students can understand historically divergent views on this topic and can see if those differences matter and why. In the post-Keynesian monetary economics literature, the 'exogenous' label is attached critically to theories that assume central banks exercise monopoly power over setting and seeking money supply goals without regard for preferences within the economy, and do so by controlling 'high powered' money in the monetary base. The signature of exogenous money is the textbook money multiplier that generates a geometric progression of loans to induced borrowers, a process constrained only by legal limits on loanable reserves. In contrast, the preferred post-Keynesian 'endogenous' view acknowledges the power of the central bank to set the price of money but not its supply. Supply is explained as a response to demand for credit that arises from within the economy and motivates the private banking system to respond to borrowers with loans that are supported with reserves supplied by an induced central bank.

Textbooks provide little help to instructors who want to present both views. In a sample of 22 undergraduate texts, Boermans and Moore (2009) found only three mentioning endogenous money, and only one adopting that perspective. The dominant view is "that the supply of money is exogenously under the direct control of the central bank through the high-powered-base

'money-multiplier' paradigm." (Boermans and Moore 2009, 13) Endogenous money is relatively more visible in the eight graduate-level textbooks in the sample, with five mentioning it; nevertheless, only three teach it. (Boermans and Moore 2009, 18)

In the absence of textbook material, contributors to this journal have been filling the pedagogical void. The four-quadrant graphical teaching model developed in Fontana and Setterfield (2009) reflects an endogenous money perspective, and the authors contrast it with the old workhorse IS-LM model and its would-be successor, the so-called New Consensus view of macroeconomics. Ehnts (2014) extends that four-quadrant graphical approach to the economy of a currency union. Rochon (2012) tackles a contemporary issue and teaches 'quantitative easing' from an endogenous money perspective. Kinsella (2010) gives students a pluralistic learning experience by contrasting the endogenous money, stock-and-flow-consistent model of Godley and Lavoie with Barro's neoclassical approach. The system dynamics model described in this paper also follows the stock-and-flow-consistent principles of Godley and Lavoie (2007) and Godley and Cripps (1983).

In this paper, we contribute to the endogenous money perspective in three ways. For economics education, we present a way to engage students so they learn about endogenous money by discovering it in a transparent conceptual model, and then they see how it can work in an equally transparent dynamic simulation model.   Secondly, for the language of post-Keynesian economics, we propose a consensus-building definition of endogenous money to mean that money is created by an endogenous feedback structure. And 'exogenous money' should be defined in terms of one-way causation; i.e., as an influence on money that is not, in turn, influenced by money or anything that money influences, such as inflation or output. An exogenous central bank, then, would be one that follows a pre-determined policy rule instead of responding to current conditions in the economy, or acts capriciously. Post-Keynesians will continue to disagree about which feedback loops are most important in the money creation process (or whether a theoretical loop has any empirical explanatory power).   Finally, for post-Keynesian modeling methodology, we add our support for system dynamics as a method of scientific inquiry and a tool for dynamic simulation of monetary production economies characterized by uncertainty, delays, nonlinearities, and feedback in historically-grounded socioeconomic and political systems. In this respect, our paper is motivated by the work of Michael Radizki, an economist and expert modeler who has encouraged post-Keynesians and institutional economists to take a closer look at system dynamics (Radzicki 1988 and 2015), and it is motivated by those who have responded to his call.[1]

The approach described here uses system dynamics (SD) learning and modeling tools in the classroom to help Lithuanian graduate students develop a systemic perspective on money and banking. They learn how to use pencil-and-paper diagramming methods to develop conceptual models, and use computer simulation models to test their understanding and investigate the structure and behavior of a banking system within a national economy. With a holistic view and an SD conceptual model that clarifies feedback effects, students literally *see* how money could be "always and everywhere" endogenous (Rochon and Rossi 2013) in contemporary monetary systems never shocked by helicopter money and no longer shocked by discoveries of gold and silver (though Rochon and Rossi argue that commodity money systems were also endogenous). An SD simulation model helps students understand "why it matters" (Palley 2002).

The students are in the financial economics master's degree program at ISM University of Management and Economics in Vilnius. They have a strong background in economics, finance, and mathematics, and are prepared for an advanced systems approach to monetary policy. The

course is intense, with nine three-hour lectures over a three-week period, while the students work in teams outside class on a project they present during the fourth week. The lectures are in the evening, after most of the students have completed a full day's work at a professionally demanding job. Students use systemic methods to interpret theories of monetary policy formulation and implementation, and place those theories in the context of real-world economies and policy-making. Special attention is given to the policies and procedures of the European Central Bank and the new institutional role of the Bank of Lithuania since the euro was adopted in 2015. Students get a strong endogenous money perspective from their main textbook, Bain and Howells' *Monetary Economics* (2009), and they also read selections from Bofinger's *Monetary Policy* (2010) and journal articles on monetary economics and SD-based economic modeling.[2]

The classroom conceptual model is eclectic and pluralistic. Developed in series of increasingly rich maps that simplify complex models of the money supply process, it integrates behavioral hypotheses translated from both orthodox and heterodox literature into diagrams of causal relationships. Even before a central bank is added to the model, students see how a rising loan demand could call forth a flow of new money from commercial banks in the form of credit income, causing an increase in the deposits component of the money stock. The credit income has a unitary marginal propensity to spend, and induced aggregate demand spurs additional loan demand and closes a positive, self-reinforcing feedback loop. The result is endogenous money. As the conceptual model takes shape, students identify pressures on interest rates that influence loan demand and close another feedback loop, but that one is a negative, counteracting loop. Money is still endogenous, but it is now governed by two feedback loops competing for dominance in a nonlinear system--one loop reinforcing the initial trend and the other counteracting it. Additional structure further embeds the money supply in a web of endogenous feedback. Eventually, we add central bank monetary policy to the model, but in two stages. First, it is exogenous and designed to guide growth in the money supply at a pre-determined rate independent of the current state of the economy. Students see that the money supply is still subject to the same endogenous forces, and that an exogenous policy shock merely activates those feedback loops. Then we add policy rules that endogenize monetary policy. One rule targets the money supply growth rate, while the other is Taylor-like and targets the interbank interest rate. Each rule responds to inflation and output gaps and seeks to close those gaps, but has different systemic effects. Subsequent behavior in the economy eventually feeds back in different ways to revise the policy rule target and close a negative monetary policy loop. But the take-away message remains the same: endogenous rule-based policies trigger all the pre-existing loops that determine the money supply, and add another chapter to the story of endogenous money.

The conceptual model provides a simple yet coherent illustrated narrative of endogenous money. Its purpose is to motivate thinking about the structure of causal relationships and their implicit behavior. Yet, a conceptual model has to be transformed into a simulation model--with specified equations and calibrated parameters--before its structural details and their behavioral implications can be analyzed. Section 3 of this paper explores the evolving conceptual model summarized above, and demonstrates a method for engaging students in systemic thinking. Then section 4 explains key structural components of the simulation model and the behavior it generates; in addition, it analyzes the results of a simulation experiment when competing theories of money creation are put to a test. The final section concludes with suggestions for instructors who want to use some or all of this approach with their students, including undergraduates. Before that, section 2 compares the endogenous perspective in economics and system dynamics, in order to clarify the use of the terms endogenous and exogenous in the remainder of the paper.

2   The Endogenous Perspective

An internal process that regulates or reinforces its own behavior is, by definition, an endogenous feedback structure. Self-regulation with adjustment towards a systemic goal is a universal function of *negative* feedback systems, with the common thermostat being the classic mechanical example of homeostasis.[3] Endogenous growth or decline requires the self-reinforcing influence of *positive* feedback loops. The internal structure of complex feedback systems includes a web of both positive and negative loops metaphorically competing for dominance. Stable systems are dominated by negative loops, while unstable systems reflect a feedback tug-of-war. Systems dominated by positive feedback loops are not sustainable; no system can persist without some counteracting forces to check tendencies towards explosion or implosion. Thus, the 'negative' forces are essential to the persistence and stability of a system. Of course, whether they operate strongly or in a timely manner are important empirical questions for any real-world system.

Richardson (1991) traces the evolution of feedback thinking in economics. Among the early 20th century examples is at least one that should interest post-Keynesians: Kalecki's (1935) macro model, translated into a network diagram by Allen (1955). Kalecki's model is reproduced in Figure 1, alongside others translated by Allen.

The engineering network terminology is unfamiliar to many of us. Yet, three feedback loops are evident in Kalecki's model. Allen observes that investment in the Kalecki model depends on the levels of income and of capital stock and that the accelerator depends on the loop involving the capital stock (Allen, p. 161).

When comparing how different economists think about a problem, placing such models side-by-side *with familiar symbols and nomenclature* can be highly instructive for both the practitioner and the student. In Wheat (2009a), for example, simple causal diagrams are used to compare three economists' models of the U.S. housing price bubble that preceded the most recent international financial crisis.

Figure 1. Feedback Loops in Early 20th Century Macro Models
Source: Allen (1955, p. 160)
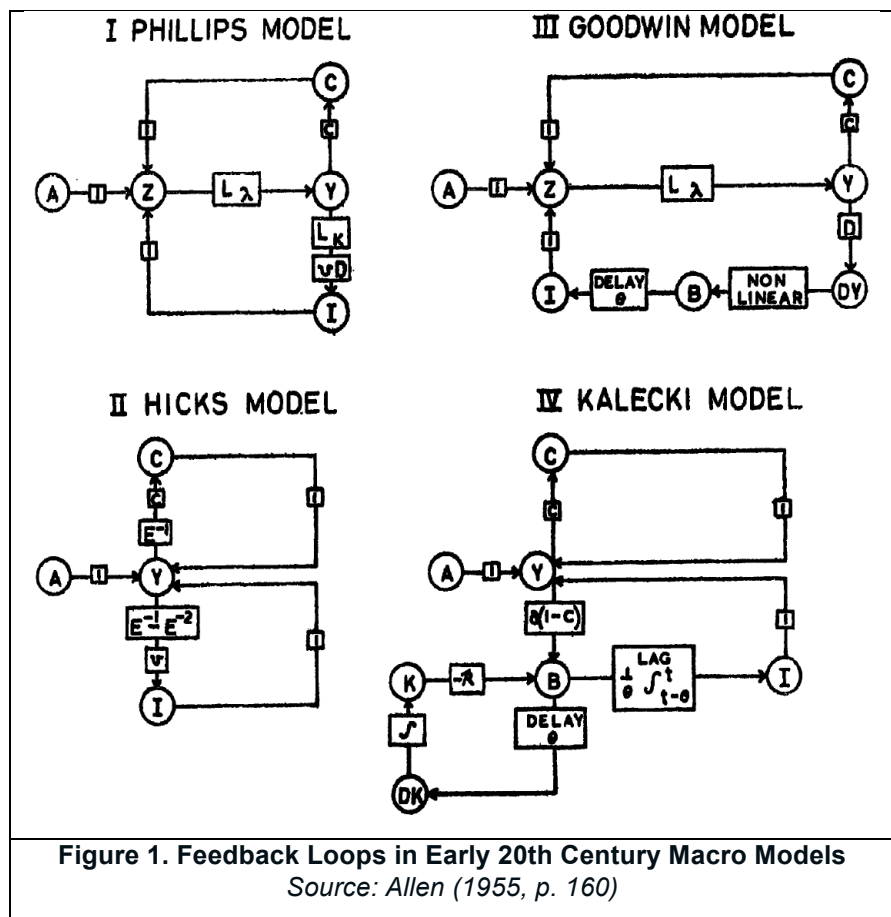
Jain and Tomic (1995, p. 125) assert that

> "[Post-Keynesians] believe that the money supply is endogenous, that is, it has a *feedback* effect. The effect of a change in the money supply runs from money to economic activity and then back to money. Thus, the monetary authority does not have complete control on the money supply. Also,

because of the endogenous nature of the money supply the relationships among money, interest rates, economic activity, and the price level are very complex." (emphasis added)

We agree, but their conclusion is based more on inference than evidence. The endogenous feedback perspective has not been explicit in the post-Keynesian literature, notwithstanding Allen's feedback representation of Kalecki's model. When we examine the origin, evolution, and usage of the endogenous money concept, we discern an *implicit* feedback perspective. An early and lonely exception is found in Davidson and Weintraub (1973), whose model was "designed to illustrate how changes in money holding impinge on the variables of the real sector, and the *feedback* of these variables on the desired demand for money" (emphasis added). Making that perspective *explicit* more often would clarify and strengthen the argument of the endogenous money school of thought by specifying how dynamics emerge from a particular internal process.

Perhaps the first printed English use of the term 'endogenous' in this context appeared in 1970, when Kaldor (1970, p. 9) wrote that "the money supply is endogenous, not exogenous." He did not elaborate in that paper on how the endogenous process works. In that particular sentence, Kaldor the economist was not much different from a novelist or historian. Since endogenous and exogenous entered the English language in the early 19th century, popular usage has been limited to specifying the *source* of change--internal (endogenous) or external (exogenous)-- without describing how change actually transpires at that source.[4] Thoreau (1849) offers a colorful example in American literature: "We don garment after garment, as if we grew like **exogenous** plants by addition without." Another early example comes from Twopeny's (1883) history of Australian town life: "Certain it is that if Federation is to be brought about, the movement must be **endogenous**."

Here are two modern examples: Stuart Kaufman's (2010) assessment of comparative advantage

> "Ethiopia is good at producing coffee, Alberta is good at producing wheat. The two should trade freely to their joint advantage. Unfortunately, this leaves both as what we call "sub-critical" economies that cannot **endogenously** generate a growing diversity of goods and production capacities, hence wealth and growth."

and David Frum's (2012) review of *Unintended Consequences: Why Everything You've Been Told About the Economy is Wrong*

> "Conard spends a lot of effort severing the causes of the crash of 2008 from the apparent expansion of 2003-2007. This seems an untenable project. The real-estate bust of 2008 was rooted in the real-estate bubble of 2003-2007. Yes, the record of the 2000s looks better if you treat the bust as some kind of **exogenous** event caused by overbearing government. But in that case, you also have to treat the real-estate bubble as an **exogenous** event. And without that bubble, the economic record of the 2000s is the worst for any period since World War II."

Popular writers seem content to leave the endogenous explanation in a black box. However, as Richardson (1991, p. 15-16) emphasizes, "The endogenous point of view *looks inside* a complex system for the causes of its own significant behavior patterns." A scientific school of thought that defines itself by an ambiguous term must interpret that term for others. Basil Moore (1983), a leading exponent of the endogenous money school, tried to 'unpack the black box' containing post-Keynesians' money supply process, but his efforts mostly aimed at substantiating how credit demand gets translated into lending.

In the case of the endogenous money school, a working definition has evolved but ambiguity remains. The evolution and refinement of an articulated endogenous money process deserves more in-depth treatment than space permits in a paper about teaching methods. Therefore, we cut to the chase and look for a current representative explanation.[5]

Wray (2007, p. 2) says "Marc Lavoie (1984) put it best when he said that loans make deposits and deposits make reserves. That will be the working definition used for endogenous money in [Wray's] paper." This *sounds* like feedback thinking, and is supportive of our conclusion that the feedback perspective is implicit the endogenous money definition. However, the loop is not closed until someone makes clear what triggers or constrains loans in the first place. A careful application of endogenous feedback thinking would be more precise. And precision is critical in this context because it concerns the crux of the fundamental question that endogenous money theorists have raised: whether lending is constrained by reserve requirements set by the central bank or by loan demand originating in the private sector.

Moreover, lack of precision when discussing endogenous processes confuses important scientific arguments. One only has to read Docherty's (2005) study of the theoretical disputes surrounding endogenous money to realize that post-Keynesians have distinctive opinions, conveyed in diverse definitions and interpretations. Even a short list reveals distinctions of high granularity; for example, whether the money is supply *weakly exogenous*, *theoretically endogenous,* or *effectively endogenous*. If that weren't enough, Palley (2002) identifies an additional ten distinctive variations of endogenous money, such as *black box*, *evolutionary*, and *portfolio*. Then there is Wray's (1992) taxonomy of six money models that range, in Likert-scale style, from *extremely exogenous* to *extremely endogenous*.

Summarizing the endogenous money supply perspective, Pearce and Shaw (1992, p. 126) call it

> "… the view [that the money supply is] determined by forces within the economy itself, such as rates of interest and the level of business activity. The central bank does not impose any limit [on money supply] but merely provides what the market needs."

This implies the existence of a boundary around the "economy itself" within which money creation occurs, and that the central bank is outside that boundary. However, from an SD perspective, a central bank that 'provides what the market needs' is clearly an endogenous component within the money creation system. In their macroeconomics textbook, Hall and Taylor (1997, p. 240) say much the same thing: "If money supply responds to events in the economy, then it no longer can be considered exogenous, for it is determined in the model."

Conscious employment of an endogenous feedback perspective encourages a method of scientific inquiry that takes the feedback loop as the fundamental unit of analysis. Causation is mutual and circular and is characterized by delays and nonlinearities. Two-way causation is not merely accepted, it is embraced because it illuminates endogenous reinforcing and counteracting tendencies. With an agreement that the feedback loop is the unit of analysis, scientific debate about endogenous processes can focus on the variables along the loops, the polarities of the loops, and changes in their relative strength over time. This enables more precision in the debate, fosters clarity, and reduces misunderstanding. Moreover, it eliminates the epidemic-like proliferation of qualifiers used to describe an endogenous process.

The endogenous perspective is central to the system dynamics paradigm. Richardson (2011, p. 221) considers it "the most significant part of the system dynamics approach for understanding complex systems." In *Principles of Systems*, Forrester (1968, pp. 4-1, 2) emphasizes the importance of properly specifying the boundary of a system before attempting to model it: "Any action which is essential to the behavior ... being investigated must be included inside the system boundary." The scientific and practical challenge is to draw the boundary just the right size: big enough to include the systemic structure responsible for behavior under study, yet small enough to be tractable. The key point is that the dynamic behavior under study should arise from "within

[the] internal structure" delineated by the chosen model boundary (Forrester, 1968, pp. 4-2). This is the endogenous perspective of system dynamics (SD).

The system boundary is one side of the endogenous coin. The other side is the feedback structure within that boundary. In order for dynamic behavior to arise endogenously (and not merely reflect an exogenous stream of time series data from outside the boundary), the parts of the structure must interact in a set of closed loops of mutual and delayed causation in which "past action" influences "future action" (Forrester 1968, p. 1-5). This is the essence of a feedback system, and it provides important guidance to those of us building SD models. Boundaries and feedback loops *define* what is endogenous and what is exogenous in a model.

When teaching the SD modeling process, I encourage students to 'model backwards' from the flows until they either close a loop—and see evidence of endogenous feedback structure—or reach the boundary of the model in the form of an exogenous parameter. There are no other ways for the causal path to end (without redefining the boundary—which is always an option).

In the rest of the paper, endogenous refers to causal feedback structure within the boundary of a model, while exogenous means one-way causation from outside the model's boundary. For the two competing perspectives on the cause of money creation, we prefer more descriptive terms. Central to the reserves-based theory of money creation is the idea that bank lending is based on the supply of reserves, and this idea is operationalized by a *loan supply* variable in the model. The alternative view is that lending is demand-based, and the corresponding model variable is called *loan demand*. Both theories are endogenous; i.e., causality occurs within the model boundary as a result of feedback processes; thus, comparison requires identifying their respective feedback structures.

3   A Dynamic Systems Thinking Approach to Money, Banking, and Monetary Policy

In this section, we discuss four progressively richer conceptual models to build the intuition needed for a dynamic perspective of the money creation process. The discussion parallels a presentation that takes place in the monetary policy classroom at ISM in Vilnius. There, however, each successive version of the conceptual model has a stand-alone counterpart in the form of a calibrated system dynamics (SD) simulation model, and students can compare simulation results and see how additions to a model's structure can change its behavior.

A conceptual model is a simplified diagram of a model's cause-and-effect structure, and its purpose is to encourage inspection, discovery, and discussion of the theory implicit in the diagram. Figure 2 is an example of a highly simplified conceptual model of a dynamic system, in this case an illustration of two key concepts in monetary economics: the monetary base and broad money. In the background are examples of two of the three key structural components of an SD model: stocks and flows.
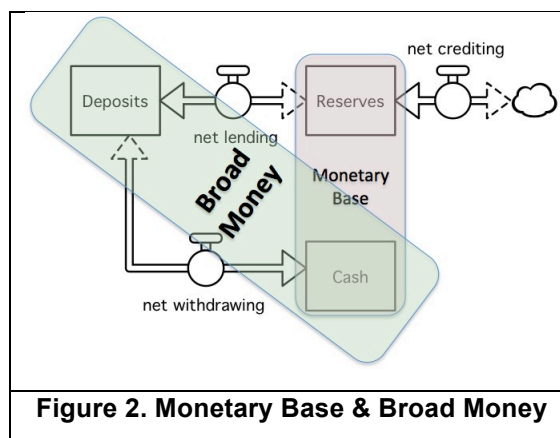
Represented by boxes, the stocks include private sector *Deposits* (one component of the broad money supply), commercial banks' *Reserves* (part of the monetary base), and private sector *Cash*

Figure 2. Monetary Base & Broad Money

(included in both the monetary base and broad money). The symbols resembling pipelines represent flows to and from the stocks: *net lending*, *net crediting*, and *net withdrawing*. A

double arrowhead is used when it is possible for flows to move in either direction, with the dotted end showing the direction of negative values. For example, if *net withdrawing* is negative, funds are flowing from private *Cash* to private *Deposits*. The small figure atop each pipeline symbolizes a valve controlling the rate at which material or information is flowing. In the simulation version of this model, an equation metaphorically opens and closes each valve, thereby controlling the flows in and out of stocks.

Aside from introducing the SD modeling concepts, the instructional value of Figure 2 is in the discussion it motivates regarding the differences between the monetary base and broad money, the factors that influence the flows, and the way *net lending* moves money in and out of the economy between *Deposits* and *Reserves*, and other ways that money is created and destroyed.

Figure 3 provides a more complete picture of the assets and liabilities of the private sector and

banking sector. The curved arrows represent causal influences. The small plus and minus signs near each arrowhead indicate the ceteris paribus polarity of the causal relationship; e.g., *lending* has a positive effect on *net lending* while loan *repayments* have a negative effect. To keep this new diagram as simple as possible, *Cash* is not shown; thus, private sector assets are *Deposits* and *Bonds P,* while liabilities are *Loans*.[6] Banks' assets are *Loans*, *Bonds B*, and *Reserves*, and liabilities are *Deposits*. The bonds represent the monetary value of funds invested in government securities; thus, they represent government debt and, for simplicity in this diagram, the total is

Figure 3. What 'Causes' Lending?

fixed (i.e., an increase in Bonds B causes a one-for-one decrease in Bonds P).
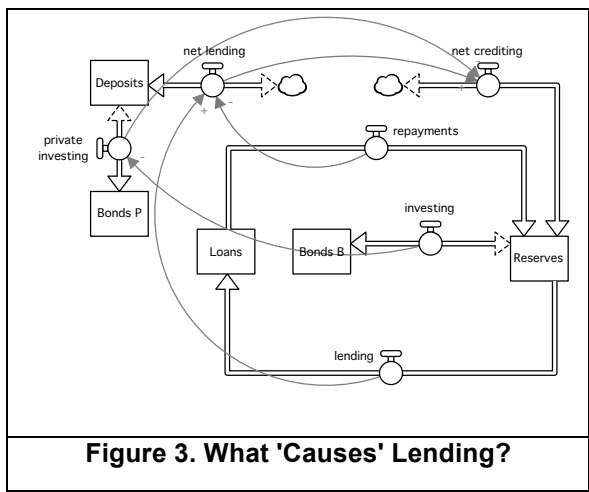
Flows of *lending* and subsequent loan *repayments* move funds from *Reserves* to *Loans* and back again. Private sector deposit accounts and commercial banks' reserve accounts at the central bank change simultaneously when loans are made and repayments occur. Banks buy bonds in the secondary market from the private sector. An increase in bank *investing* reduces *private investing* and raises the level of *Deposits*. For simplicity, other types of investments are ignored.

Readers with a nodding familiarity with SD may be surprised to learn that the third structural component of a typical SD model—the closed feedback loop—is not present in Figure 3, notwithstanding the impression of feedback suggested by the 'loopy' causal arrows and the implicit circular flow of funds in the diagram. A feedback system is defined by <u>closed</u> loops of mutual and delayed causation in which "past action" influences "future action" (Forrester 1968, p. 1-5). Suffice it to say, there is a missing link that prevents a closed loop in Figure 3; namely, the absence of an explicit <u>cause</u> of the *lending* outflow from *Reserves*. There is no causal arrow pointing to *lending* (analogous to the error of omission attributed to Wray on page 5).

Although *lending* flows from *Reserves*, that does not necessarily mean that *Reserves* cause *lending*. The mere existence of an outflow from a stock is insufficient evidence to conclude that the stock influences its own outflow. The only universally true causal statement concerning a stock and its outflow is easy to overlook: causality always goes from the outflow back to the stock of origin; i.e., *lending* subtracts from *Reserves*. Of course, it may also be true that the level of *Reserves* influences the rate of the *lending* outflow, but that is an empirical question and not an axiom.[7]

The missing link in Figure 3 is deliberate. It serves to focus our attention on an essential question answered differently by the two theories of the money creation process: whether lending in a banking system is reserves-based or demand-based. In terms of Figure 3, the unanswered question is: "What causes *lending*?"

Figure 4 extends the boundary of the conceptual model and motivates discussion of whether lending is governed by the supply of reserves or the demand for loans. Moreover, several closed feedback loops and two parameters (the reserve ratios) have been added. To keep the conceptual model simple, all other parameters in the model (e.g., delay times and elasticities) are not shown in this diagram.
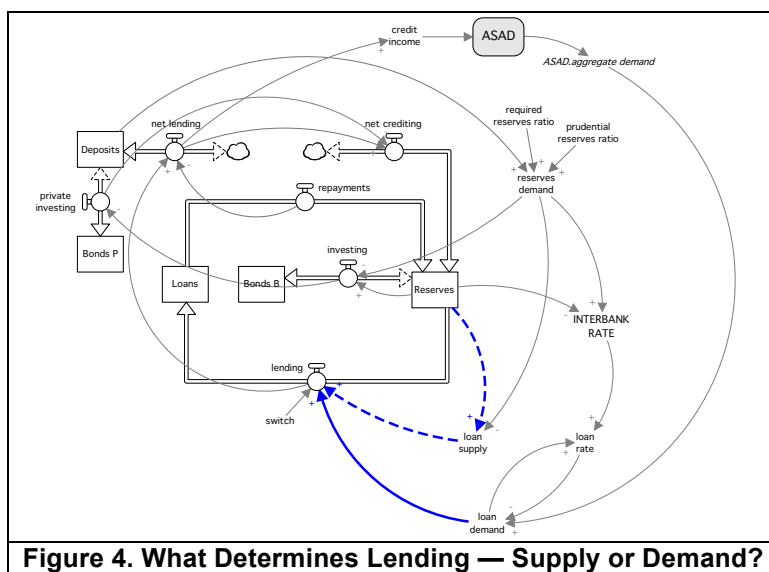
Focus on the two arrows—causal links—converging on the *lending* flow. The dashed link represents the

Figure 4. What Determines Lending — Supply or Demand?

hypothesis that *lending* is driven and constrained by *loan supply*.[8] The solid link reflects the view that *lending* is driven and constrained by *loan demand*. In the simulation model, a switch is used to activate only one of these causal links during a simulation run. Thus, by activating one link and then the other in two successive simulation runs, it is possible to compare the behavioral response of the model under each theoretical assumption and assess the two perspectives.

The shaded oval *ASAD* contains a simple aggregate supply and demand sub-model, an input to which is *credit income*. *Credit income* equals *net lending* and, on the assumption that borrowers spend all of their loans, the marginal propensity to spend *credit income* equals 1.0. The structure within the sub-model determines *aggregate demand* which, in turn, feeds back to influence *loan demand*. Thus, the banking system model functions within the context of a simple macroeconomic model, each influencing the other. Note the closed loop running from *aggregate demand* to *loan demand*, *lending*, *net lending* (change in money supply), *credit income*, and eventually back to *aggregate demand*. The polarity of each link along this loop is positive (including those along this loop inside the ASAD sub-model), making it a positive feedback loop that exerts a reinforcing effect for good ('virtuous' circle) or ill ('vicious circle').[9]

A negative loop, defined by an odd number of negative links, exerts a counteracting effect. It is the classic 'thermostat' loop that seeks adjustment of a system condition (e.g., room temperature) towards a goal for that condition (e.g., desired temperature). In Figure 4, for example, *loan supply* is part of a negative loop that runs through *lending*, *net lending* (change in money supply), *Deposits* (money supply), *reserves demand*, and eventually back to *loan supply*, seeking to adjust *Reserves* to match *reserves demand*.

The key variables in both money creation theories are embedded in several feedback loops that intersect the money stock (*Deposits*) and changes in that stock (*net lending*). With either theory, money is endogenous; i.e., it is created by mutual and delayed circular causation within the boundary of the model. The interlocking loops vary in strength over time, making it problematic for negative feedback loops to reach the goals they seek in a timely manner. Even the simple conceptual model in Figure 4 suggests the challenge facing endogenous monetary policy makers

who respond to noisy economic indicators and try to 'fine-tune' the money supply or its rate of change towards a goal under dynamic conditions in which the counteracting and reinforcing loops are competing for control of the system. Yet, Friedman's (1968) proposal for an exogenous monetary policy could only be implemented by policy makers willing to put money on automatic pilot and ignore what's happening in the economy.

The final version of the conceptual model considered here is displayed in Figure 5. The new feature on the right is a monetary policy based on a Taylor rule (Taylor 1993), including five new variables: *output gap*, *inflation gap*, *target interbank rate*, *interbank rate gap*, and *planned OMO bond purchases*.

The *OMO bond purchases* flow implements monetary policy via open market operations in the bond market. When the central

Figure 5. Conceptual Model of 'Loan Supply' and 'Loan Demand' Theories of Money Creation

bank sells bonds to banks, that is a negative purchase and funds flow from *Reserves* to *Bonds*. Another simplifying assumption is that the transactions are solely with banks, even though non-bank dealers participate in OMO transactions in some countries.

Since it is an endogenous monetary policy, it must operate along at least one negative feedback loop designed to counteract undesirable trends in key economic indicators such as inflation and output measures such as capacity utilization or employment. When those indicators are moving in the wrong direction and exceed thresholds, monetary policy aims to counteract those movements; i.e., slow or reverse them ('lean against the wind'). The bold arrows in Figure 5 trace a feedback structure that consists of three negative feedback loops involving gaps in output and inflation. One loop includes only the *output gap* effect on monetary policy, another includes only the *inflation gap* effect, and the third includes both gaps. To visualize the feedback process and the shifting dominance between loops, consider the following thought experiment.

Assume, for example, a shock to exports that boosts *aggregate demand*, motivates *loan demand*, and feeds back to accelerate the growth in *aggregate demand*. Gaining steam, the positive loop generates output and inflationary pressures leading to an *output gap* and *inflation gap*. Eventually, the gaps prompt a change in monetary policy, and the negative loop raises the *target interbank rate*, reduces *OMO bond purchases*, reduces *Reserves*, raises the *interbank rate* in the overnight money market, and impacts *loan demand*. That's where the negative policy loop intersects and seeks to counteract the positive inflationary loop. Eventually *loan demand* weakens and slows the growth in *aggregate demand*, hopefully just enough to stabilize output and prices without triggering a vicious downward spiral.[10]

A conceptual SD model, while useful for simplifying and clarifying a complex causal theory, can only be suggestive about the set of structural and behavioral hypotheses that comprise the theory. When the model is specified and calibrated with equations and parameter values, however,
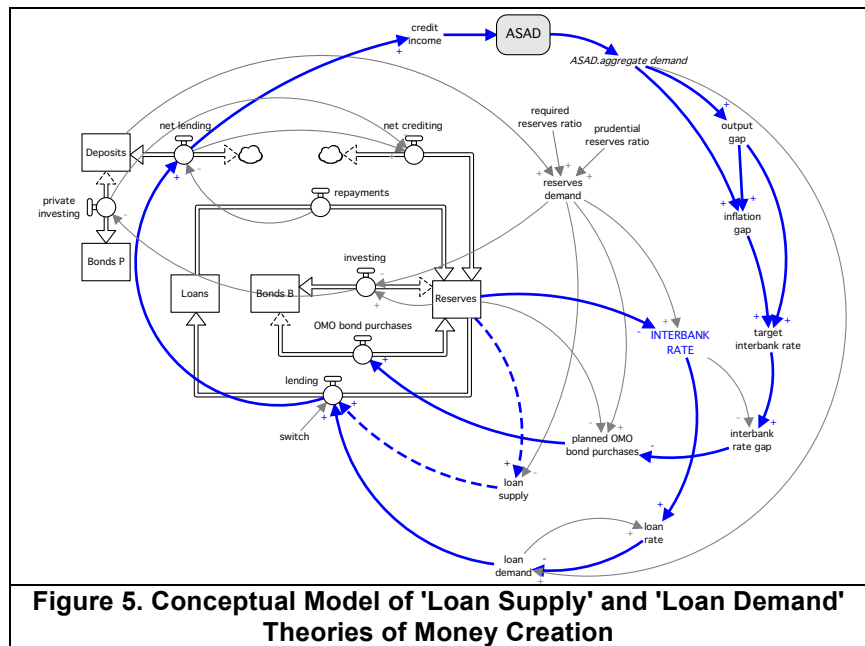
structural details—and their behavioral implications—can be analyzed. The next section discusses some of the structure of the simulation model and the behavior it generates.

4   A Systems-based Simulation Approach to Money, Banking, and Monetary Policy

Specification and calibration[11] convert the conceptual model in Figure 5 into a simulation model that can generate dynamic behavior patterns of the *levels* of stocks (e.g., euros) and the *rates* of flows (e.g., euros per year). The simulation modeling methodology now known as system dynamics (SD) began with Forrester's (1958) microeconomic analysis of industrial dynamics, and has developed into a widely used analytical and policy design method in the subsequent six decades.[12] In this section, we discuss the key structural feature that differentiates the two money creation theories.[13]

The contentious equation in the money creation process is *lending*. The reserves-based perspective has an opinion about the structure of the *lending* equation that is different from one that would be specified by the demand-based school of thought. These opponents might agree on every other equation in a macroeconomic model, and that is the assumption we make here for the purpose of understanding the meaning and significance of that one structural difference of opinion. Our focus in this section is on (a) understanding two ways to write the *lending* equation and (b) interpreting two successive simulation outcomes when first, one version of the equation is functional, and then the other.

To enable testing the impact of each theory separately, we let the *lending* variable equation contain alternative terms, controlled by an on/off switch (*s = 1 or 0*):

(1)   lending = ILD +s*loan demand gap +(1-s)*min(loan supply, loan demand gap)

where

(2)   ILD = initial loan demand

(3)   loan demand gap = loan demand – ILD

(4)   loan supply = (Reserves – reserves demand) / reserves adjustment time

(5)   reserves demand = (required reserve ratio + prudential reserve ratio) * Deposits

When s = 1 in equation 1, *lending* is demand-based and equals *loan demand*.[14] Otherwise, *lending* is reserves-based and depends on the value of the minimum function in equation 1. Purists from the reserves-based school might balk at including *loan demand gap* in equation 1. Nevertheless, it is inconceivable that *lending* could be higher than total *loan demand*. It is important to understand what this means in terms of model structure: it means that the feedback loops that influence *loan demand* and are central to the demand-based perspective also influence the reserves-based process of money creation. Cutting those loops would permit banks to lend more than the economy wants to borrow and, as implausible as it sounds, that is the implicit structure in the textbook money multiplier model.

For the simulation experiment, the model is initialized in equilibrium so the impact of the shock test is easily observed. That is, when the simulation begins, the net flow for each stock is zero, *Reserves* equal *reserves demand, loan demand gap* equals zero, *lending* equals *ILD, lending* and *repayments* are equal, and *net lending* is zero.[15] The test procedure involves shocking the model with a change in investment spending within the *ASAD* sub-model, and comparing the effects on *lending* and the money supply (*Deposits*). The shock is in the form of a monthly stochastic, white

noise disturbance with a mean of zero and a standard deviation equal to six percent of investment spending (equivalent to about one percent of aggregate demand). The stochastic shock was seeded in order to replicate the random noise and enable comparison of the experimental outcomes. The results of the simulation-based comparison of the money creation theories are displayed in Figure 6, with the impacts on *lending* and the money supply shown in the top and bottom frames, respectively. In both frames, curve 1 reflects the first shock, when lending is demand-based (s = 1), and curve 2 reflects the reserves-based assumption in the second shock.[16]

The curve patterns in Figure 6, therefore, reflect the random shock and the money theory selected. In addition, there is a background effect, stemming from the monetary policy rule in the model. Initially, the random shocks kindle inflation (not shown here). The inflation is mild but greater than the monetary policy target of zero. Thus, open-market operations kick in and put downward pressure on *Reserves* and upward pressure on interest rates during the early years, and then reverse that monetary policy stance to recover from the induced recession during the later years.[17]

The constraining influence of the minimum function in equation 1 is evident during the first five years of the simulation period, when the two theories generate identical behavior. During the induced recession, *loan demand* is below its initial value, making the *loan demand*

Figure 6. Response to Stochastic Investment Shock

gap negative and lower than *loan supply*. In that case, it does not matter if the theory-selection switch is on (s = 1) or off (s = 0). Either way, equation 1 reduces to the same terms: *lending* equals *ILD* plus *loan demand gap*. During a recession, therefore, the demand-based theory of *lending* (and money supply) dominates the reserves-based theory. Only the textbook money multiplier theory would suggest otherwise.

During the recovery period (years 5-10 in Figure 6), the demand-based theory generates higher *lending* and more growth in the money supply, compared to the reserves-based theory. The *loan supply* constraint is dominant (i.e., the smaller term) in the minimum function. Of course, the degree of reserves constraint depends on the strength of the 'animal spirits" driving the recovery, which is an empirical question. Nevertheless, the policy implication of the simulation test is reminiscent of monetary policy folk wisdom: 'It's easier to pull on a string than push on it.'

From an SD perspective, an important take-away message is that feedback loops driving changes in *loan demand* represent a major source of endogenous influence on the reserves-based theory. If those loops are cut (as they were in a third simulation not displayed here) when s = 0, *lending* is higher than *loan demand* during the recession period, an impossible outcome yet comparable to the behavior arising from the textbook money multiplier model.[18] The endogenous feedback perspective helps us better understand what demand-based money and reserves-based money really mean, and why their similarities matter as much as their differences.

The money supply should be described as endogenous in both theories, each of which places the central bank, aggregate demand, and commercial banks inside the model boundary, with the
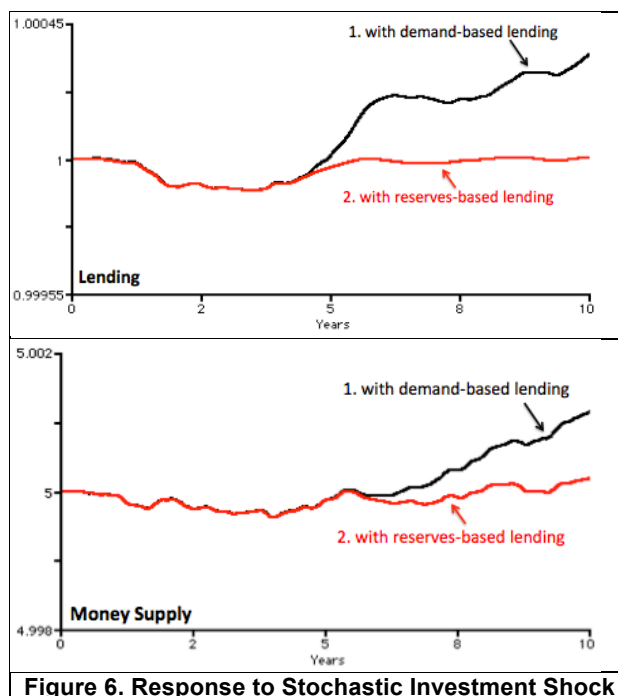
central bank responding to economic conditions. Acknowledging that both theories are endogenous does not mean their differences are insignificant. Continuing to contrast the two perspectives on money creation ('teaching it both ways') is important for at least two reasons. First, it is important to spotlight the misleading money multiplier. It's not surprising that Colander (2010, p. 716) calls it a "pedagogical crutch" in textbooks.

A more fundamental reason raised by this analysis concerns the question of how *credit income* (which equals *net lending* in Figures 3 and 4) is actually used. Although that issue is beyond the scope of this paper, suffice it say that even partial reliance on *credit income* to finance current business operations means that money is, in effect, an enabling factor of production. This is relevant to the distinction between the two money creation perspectives, as emphasized by the endogenous money school of thought (e.g., Davidson 1972, Godley and Crips 1983, Moore 1983, and Lavoie 1984). When the reserves-based theory generates 'new' *lending*, that follows from an initiative taken by the central bank in reaction to inflation and output conditions in the economy. Of course, business borrowers on the receiving end have plans for spending the 'new' *credit income,* but those plans are unlikely to include prior reliance on an open line-of-credit used for advance payments to workers and suppliers. Demand-driven lending, however, is consistent with credit income usage for anticipated costs of current operations. If money enables employment of factors of production (especially during inflationary, expansion periods), it is not neutral with respect to the supply side of the economy, in contrast to the 'consensus' among neo-classicals and New Keynesians. In such cases, money matters more than monetarists realized.[19]

We concur, therefore, that money is always and everywhere endogenous. Even if money creation becomes constrained by the availability of *Reserves*; the constraining process itself is endogenous. The feedback perspective illuminates this structure, and simulation shows how it can work in practice. Graduate students at ISM-Vilnius gain this insight during the second lecture of the course. Each lecture aims to add value with the systemic perspective and dynamic modeling. Going further, students start owning this approach when they engage in a model-facilitated research project. In the final section, we suggest some projects for graduate students, and also discuss ways to engage undergraduates.

5   Engaging Students with Systems Thinking and Simulation

[*to be added*]

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[1] For example, John Harvey (Harvey 2001, 2002, 2006, and Harvey and Klopfenstein 2001).

[2] To facilitate development of the systemic perspective, students receive a free 30-day, fully functional license to use *iThink®* system dynamics modeling software, generously provided by isee systems inc. (www.iseesystems.com). An advanced version of the software is *STELLA Professional®*, which has been used to produce the model diagrams in figures 2-5.

[3] Homeostasis is a trans-disciplinary term, as suggested by its appearance in 276 articles in 16 broad scientific categories in the online *Encyclopedia of Life Support Systems* (http://www.eolss.net/Freecat.aspx).

[4] **Endogenous** (adjective):"growing or proceeding from within," especially with reference to a class of plants..., 1822, from *endo-* "within" + *-genous* "producing." **Exogenous** (adjective): growing by additions on the outside," 1830, from Modern Latin *exogenus* (on model of *indigenus*); see *exo-* and *-genous*. *Online Etymology Dictionary* (http://www.etymonline.com).

[5] Another working paper by the author examines the theoretical and empirical aspects of endogenous money. It makes a stronger case for defining endogenous money in terms of feedback structure to unify and clarity the concept while maintaining a fertile ground for constructive dissent about the details of its structure. Tentative title: "Endogenous Money: a Feedback Perspective that Tolerates Fifty Shades of Gray."

[6] The money supply in Figure 2 is represented solely by the *Deposits* stock, but the simulation model also includes a stock of Cash that adjusts when a desired cash-to-deposit ratio responds (slightly) to changes in a deposit interest rate. When the model is calibrated, the *Deposits* and *Cash* stocks are initialized with numerical values that sum to an amount corresponding to a money category correlated with transactions in goods and services (e.g., M_2 in the United States).

[7] However, there can be no outflow if the level of a stock is zero; that is an axiom. But the 'stock-out' effect is a special case; it is not the normal mode of control in those empirical cases where stocks influence their outflows.

[8] Here, the difference between *Reserves* and *reserves demand* defines excess reserves. This excludes prudential reserves determined by the prudential reserves ratio.

[9] The polarity of a loop depends on the number of negative links it contains. A positive loop contains an even number of negative links (including none), while a negative loop contains an odd number. This is analogous to the multiplication rule for determining the sign of a product.

[10] Counteractive pressure may not lead to reversal or even effective slowing of the trend. In a complex economy and in the simulation model, monetary policy is not the only force operating on *aggregate demand*, and the existence of the policy loop is no guarantee that a counteractive adjustment will occur in a timely manner or with sufficient force or without undesirable unintended consequences.

[11] Specification refers to formulating equations for endogenous variables that influence the flows in an SD model. Specification of stock equations is done automatically by the SD software, using a numerical integration process; thus, stocks accumulate their flows. Calibration refers to estimating exogenous influences on the model, which

should be limited to constant parameters since the SD paradigm focuses on behavior emerging from endogenous feedback loops instead of being driven by exogenous time series data (Forrester 1968; Richardson 2011).

[12] See Barlas (2002) for a thorough yet accessible introduction to the discipline and Radzicki (2009) regarding system dynamics' contribution to economic modeling. For pedagogical applications to economics, see Wheat (2007, 2009a, 2009b).

[13] Readers interested in more detail should contact the author to obtain a copy of the model with documentation.

[14] Bank accounts can go negative in real life; thus, in the model, *Reserves* could go negative (but never do). That is why no outflow control is included the demand-based portion of equation 1.

[15] For the experiment, the following parameter settings are used in equations 1-5: *required reserve ratio* is .05, *prudential reserve ratio* is .05, initial *Deposits* are 4.5 trillion euros, steady state *ILD* is 1.0 trillion euros/year, and *reserves adjustment time* is 1 year. Also, steady-state *aggregate demand* is 10 trillion euros/year and the initial *money supply* is 5 trillion euros, of which the currency component is 10 percent in steady state. The *inflation target* is 0 in the Taylor rule equation to satisfy the initial equilibrium conditions, and the policy coefficients are 0.5 for both the *inflation gap* and the *output gap*. During the simulated ten-year time period, output capacity is held constant. All parameter assumptions in the model can be easily modified for additional testing and analysis. The complete model, including documentation and instructions for obtaining a free run-time version of the SD modeling software, is available on request.

[16] The curves have been exponentially averaged to smooth the patterns generated by the monthly stochastic shocks.

[17] Small shocks yield small differences. Inspection of the vertical scales in both graphs reveals that the differences are small, relative to the magnitudes. If the scales began at zero, no differences would be discernable in either graph. Nevertheless, the comparative patterns of behavior emerging from the two different theories are consistent and distinctive, and do not depend on the seed selected for the stochastic shock.

[18] Cutting a feedback loop and observing the impact on a model's behavior is a standard structure-behavior test to identify the source of dynamics in a system dynamics model. See Forrester and Senge (1980) and Barlas (1996).

[19] In an extended version of the model described in this paper, part of credit income is used for advanced payment of anticipated labor costs.