In Defense of System Dynamics: A Response to Professor Hayden

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18 March 2007

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In a recent paper in this journal, Professor Gregory Hayden (2006) argues that system dynamics is an inadequate tool for explaining the institutional systems principles of hierarchy, feedback and openness. The purpose of this paper is to show that Professor Hayden's claims are, for the most part, misguided and, in some instances, patently incorrect. Moreover, we will reinforce the view that combining system dynamics with institutional economics can be a very powerful approach to heterodox economic analysis [Radzicki (1988a, 1990, 2003)].

Heirarchy

Hayden begins his criticism of system dynamics by discussing the notion of hierarchy in systems. He notes that "[h]ierarchies exist to ensure that…happenings [in complex systems] are happening as they should happen" and then reproduces a figure by Robert Boyer (2001), which purports to show the hierarchal nature of constitutionality and rulemaking. Hayden objects to Boyer's figure because he feels it makes "hierarchy into a spatial order, rather than an institutional process…" (528). Moreover, he objects to Boyer's use of arrows with plus and minus signs in the figure because "[d]eliveries among institutions and organizations are not a matter of simple pluses and minuses" (529).

Up to this point in his paper, we have no quarrel with Hayden. However, we wonder why he believes that Boyer's figure is evidence that system dynamics is an inappropriate tool for incorporating hierarchy into institutional analysis. Boyer's figure is not a system dynamics model and, as far as we know, Boyer is not a system dynamicist. Indeed, the precise concepts that Boyle is trying to convey with his arrows and plus and minus signs are not clear to us, and he does not appear to be using the arrow and polarity nomenclature in the same way that a system dynamicist would. At the risk of stating the obvious, because a figure includes arrows with plus and minus signs does not make it a system dynamics model. To make a connection of this sort is a non sequitur of the highest order.

Hayden's critique of Boyer's model does, however, raise an important question. What, if anything, does the system dynamics approach to modeling have say about system hierarchy? System dynamics models are almost always nonlinear, which essentially means that they, and the actual systems they represent, contain limiting factors. Stated differently, from a system dynamics perspective, nonlinear relationships typically define a system's approach to its limiting factors.

Conceptualizing and modeling systems as nonlinear is important to the issue of hierarchy because nonlinear systems must be studied and solved holistically. In other words, the behavior of a nonlinear system is due to both the behaviors of its individual parts and the particular connections and interactions between its parts.[1] As such, nonlinear systems do not really consist of top-down hierarchies such as that described by Boyer,[2] but are better categorized as complex interactive processes.

Another issue related to hierarchy in system dynamics modeling involves the recursive nature of continuous simulation on a digital computer. System dynamics models are solved by having the computer step through time and calculate the amount of "stuff" that has accumulated in each of a system's stocks at every step along the way. There is a defined past, present and future in all system dynamics models and events unfold in the order that they do in the real world. In other words, in a system dynamics model "happenings happen as they should happen."

Feedback

Next, Hayden discusses the concept of feedback and its appropriate use in institutional economics. He notes that feedback is a form of inter- and intra-systemic control in which systems utilize various material and information flows for guidance. He then defines negative and positive feedback. With respect to the former he writes that "[n]egative feedback, thus, leads to the convergence of system behavior towards some goal" (530). With respect to the latter he writes that "[p]ositive feedback processes, in which positive feedback overwhelms negative feedback, tend to be destructive to the system because a change in the original level of the system provides an input for further change in the same direction" (530). While Hayden's description of positive and negative feedback processes is only a sidebar to his main arguments, we feel compelled to make two points. First, although negative feedback loops are indeed goal-seeking, they can often <u>destabilize</u> systems and cause them to oscillate if there are delays in their corrective actions. Second, positive feedback loops need not be "destructive to the system." In fact, they can form either vicious or virtuous circles and can sometimes even work to stabilize

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[1] By contrast, the behavior of a linear system is simply the sum of the behaviors of its parts. As such, a linear system can be broken down into its component pieces, the pieces can be studied in isolation, and the overall system behavior can be determined by aggregating the individual behaviors.

[2] This should not be confused with the notion of model super-sectors, sectors, and sub-sectors which although hierarchical, are merely conceptual tools for laying-out the structure of a system dynamics model for an audience in an orderly fashion.

systems.[3] Path dependent behavior,[4] which can be either good or bad, bandwagon effects, and increasing returns to scale are examples of processes that are generated by positive feedback loops.

Hayden goes on to note that "[t]he feedback concept comes from cybernetics…[which] is mechanistic, based on physics, and very concerned with energetics – hardly the base for studying feedback control in social systems" (530). Based on this statement, it appears that Hayden believes that the feedback concept originated in cybernetics. Moreover, the statement makes us wonder if Hayden is also implying that the intellectual predecessor of system dynamics is cybernetics. If our interpretations of Professor Hayden's statement are correct, we'd like to call his attention to George Richardson's (1991) book Feedback Thought in Social Science and Systems Theory.[5] In this book Richardson traces, in egregious detail, the loop concept (which embodies both the concept of feedback and the concept of circular causality) in the social sciences from the golden age of ancient Greece to the present day, and identifies two distinct threads. The first is indeed the cybernetic thread, which stems from the work of Norbert Weiner and the Macy Foundation conferences of the 1940s and the second is the servomechanism thread, which stems from the world of control engineering. Richardson makes a compelling case that social scientists working within the former thread view feedback as the mechanism of homeostasis and utilize it to address issues mainly related to control and communication. Positive feedback processes are rarely, if ever, utilized by researchers working within the cybernetics thread. Social scientists working in the latter thread, on the other hand, focus on understanding the causal relationship between a system's feedback structure (both positive and negative loops) and its dynamic behavior.[6] Richardson (correctly) places system dynamics squarely within the servomechanism thread.[7]

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3 Jay Forrester (1980, p. 14) likes to tell the story of a patent application he once submitted to the U.S. government, in which he described a hydraulic control device containing a positive feedback loop that worked to stabilize the system. The patent was initially rejected because the patent examiner did not believe a positive feedback process could add stability to a system. Of course, this was the characteristic that made the device innovative in the first place!

4 See for example Sterman (2000, Chapter 10) and Barnes et al. (2004).

5 Richardson originally did the research for this book as his Ph.D. dissertation at MIT. Jay Forrester supervised the dissertation.

6 For more detail on the cybernetic and servomechanism threads and their relationship to system dynamics see Radzicki (2007).

Hayden next introduces figure 2, "a digraph expression of part of a social fabric matrix for the management of the surface water of the Platte River in Nebraska…" (531) and offers it as an example of the proper use of hierarchy and feedback in institutional economics. He defines the "feedback control paths" in this figure to be "sets of institutional processes at work" (530).

We have no particular disagreement with Hayden over this figure beyond its fairly cluttered appearance. In fact, from a system dynamics point of view it would appear to be equivalent to a sector diagram of a system dynamics model, with the "feedback control paths" simply defining some of the main causal relationships between the model's sectors. A sector diagram such as this can be created prior to the construction of a system dynamics model as part of the knowledge elicitation/brainstorming/model conceptualization process, or after the construction of a system dynamics model as part of the model's documentation. In the former case, utilizing a social fabric matrix as a tool to elicit knowledge from experts and stakeholders, and to conceptualize a problem from a system's perspective, as a precursor to building a system dynamics model is excellent practice. Indeed, Roderick Gill (1996) did just this in his efforts to solve local and regional environmental planning problems using system dynamics.[8]

Openness

Next, Hayden discusses the concept of openness and notes that it is a characteristic of all systems and thus needs to be recognized in institutional modeling. According to Hayden, openness means that systems exist within diverse environments with which they continuously exchange information, energy, materials, and ideas. Again, we

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[7] Actually, we agree with Hayden that cybernetics is not an appropriate methodology for institutional analysis. In fact, the focus in cybernetics on negative feedback processes and homeostasis is more consistent with orthodox economics because market-clearing behavior and equilibrium are both based on dominant negative feedback processes. The servomechanism perspective, on the other hand, in which dominant positive feedback loop behavior is common, is entirely consistent with institutional analysis. Increasing returns, path dependency, far-from-equilibrium phase transitions and the like (i.e., non-equilibrium, evolutionary, behaviors in which nonlinearities and limiting factors reign-in a system's behavior, not equilibrating forces) are processes driven by positive feedback. This is the type of feedback that economists such as Gunnar Myrdal were referring to when they wrote about "circular and cumulative causation."

[8] Actually, Gill and Wolfenden (1998) later developed an "IDeaMaP" approach, which they feel is a superior knowledge elicitation process for system dynamics modeling.

have no quarrel with Hayden on this point as the concept of openness is intimately intertwined with system dynamics modeling.

Hayden goes on to criticize Boyer's model for not including an environment and thus for not being open. However, he then says: "The same incorrect assumption is made for Forrester-type system dynamics computer programs" (532). Unfortunately, Hayden is completely incorrect when he makes this statement.

Place Figure 1 About Here

Figure 1 presents a very simple system dynamics model, which was created solely to address Hayden's claims about openness and system dynamics models. The model portrays an open system that receives raw material <u>from</u> its environment, converts it into both goods and pollution, and then ships the goods and expels the pollution <u>to</u> its environment.[9] The system's environment is represented in the model by the "cloud" at the beginning of the "Shipments of Raw Material from Environment" flow and the "clouds" at the end of the "Expulsion of Waste to Environment" and "Shipments of Goods to Environment" flows.

Although the overwhelming majority of system dynamics models of socioeconomic systems that have been created over the years are open, it is technically possible to create a system dynamics model that is closed. The issue of when it is "correct" to do this, however, is problem specific. Simply put, if the problem the model is addressing calls for a closed system, a closed system should be created.[10]

A more important issue that is closely related to Hayden's claim that system dynamics models are closed is that of specifying a model's boundary. This modeling task involves thinking hard about the elements of the real world system that should be included in, and excluded from, a model's structure. In the model presented in Figure 1, the cloud at the end of the "Expulsion of Waste to Environment" flow defines a portion of the model's boundary. In other words, where the pollution goes when it flows into "the environment" is not thought to be important to the modeling problem, nor kept track of by the computer – it is out of the model's boundary. If however, after some

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[9] Generally speaking, an open system is "dissipative" and a closed system is "Hamiltonian." Systems of the latter type do <u>not</u> exchange inputs and outputs with their environments. See Radzicki (1988b) for some of the technical details surrounding dissipative and Hamiltonian systems.

[10] Closed systems are often appropriate in fields such as astrophysics when, for example, problems related to the evolution of the universe are being modeled.

investigation, these details are deemed important to the modeling problem,[11] the model's boundary must be expanded.[12] This is accomplished by replacing the cloud with a stock that accumulates the flow of pollution into the environment, and by specifying the feedbacks from this stock to other parts of the system.[13]

Professor Hayden is completely correct to note the importance of the open systems concept in contemporary evolutionary economics. Unfortunately, he appears to be confusing the closed loop (endogenous) explanations offered by system dynamics models with the notion of a closed system. Figure 1, however, clearly reveals that it is possible to have closed feedback loops in an open system dynamics model. Indeed, this sort of modeling is de rigueur in the field of system dynamics.

Continuing his discussion of openness, Professor Hayden then notes that "because real-world systems are constantly open to their environments, equilibrium is not possible" (532). Again, we have no quarrel with this observation per se. However, it's clear that Hayden is making this point in an effort to attack system dynamics and, in doing so, reveals his confusion between properties of models and properties of real world systems.

Although system dynamicists believe that actual systems rarely, if ever, exist in a state of equilibrium, it is quite common in system dynamics to start a model in equilibrium and then knock it out with a shock from its environment so that its "pure" (disequilibrium) response can be observed. Model testing is undertaken in this manner because (a) it simply makes it easier to see the response of the system to the shock and (b) a fundamental idea in system dynamics modeling is that the structure of a system (which includes the details of its institutions) is responsible for its behavior and thus the proper use of a model is for testing policies (i.e., changes to the system's structure) which are aimed at making the actual system robust. A robust system will respond "well" to shocks from its environment, regardless of the timing or direction of the shocks.

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[11] Say, for example, because they are found to be important limiting factors for the system and that the system responds significantly to these factors.

[12] The classic example of expanding the boundary of a system dynamics model involves Forrester's (1969) Urban Dynamics model. This model was criticized for, among other things, excluding the suburbs (i.e., the suburbs were the city's environment – outside of the model's boundary). In response to this criticism, the suburbs were added to revised versions of the model. Surprisingly (to some) this addition to the model's structure did not lead to any policy recommendations that were different from those generated by the original analysis [See Graham (1974) and Schroeder (1975a and 1975b)].

[13] See the discussion in Sterman (2000, pp. 222-225). In Figure 1, if a cloud were replaced by a stock, it would appear inside of the box representing the "Model Boundary."

Figure 2 presents two simulations (an "equilibrium base" run and a "technological improvement" run) of the simple system dynamics model presented in Figure 1. The system is knocked out of equilibrium by an exogenous shock – i.e., a technological discovery from the system's environment that allows more goods, and less pollution, to be produced from the same amount of raw material. Inspection of the figure reveals that both inventory and shipments of goods to the environment increase in response to the introduction of new technology. The simulations also reveal that equilibria are indeed possible in an open systems model. However, as stated above, this does not imply that the actual system being modeled is ever in a state of equilibrium.

Finally there is another, more important, way to think about the issue of open versus closed systems, to which we'd like to call Professor Hayden's attention. System dynamicists have long argued that the true value from using system dynamics comes from the process of modeling, not from any particular model.[14] That is, the insights obtained from the iterative process of problem definition, model conceptualization, model testing, model revision, and so forth generate the value, not the final product. Indeed, although system dynamics models technically evolve as the dominance of their feedback loops (i.e., their active structures) endogenously change during a simulation run, it is really the modeling process that causes them to evolve as modelers acquire improved insights into how system structure causes system behavior. Stated differently, the system dynamics modeling process is entirely about learning and improving a decision maker's mental model of the system experiencing a problem.

Fitting System Dynamics Models to Time Series Data

Another problem that Professor Hayden has with the application of system dynamics to institutional economic analysis has to do with curve fitting. He writes:

> Forrester systems literature emphasizes that models are to mimic databases, meaning that the coefficients are to be adjusted with the capabilities of the computer program until the model will reproduce historical database results for particular entities of interest…If the goal is to juggle data and manipulate coefficients until a particular historical path is reproduced, what the nodes in the model are called or how they work in the real world is not a concern. It is coefficient adjustments that generate validity. The coefficients are not adjusted because of statistical analysis or institutional theory, but, rather, to reproduce a database (533).

[14] See Forrester (1985).

Unfortunately, Professor Hayden couldn't be more incorrect on this point, at least vis-à-vis proper system dynamics modeling practice.[15]

System dynamicists do not believe that it is profitable to think about models as being either "valid" or "invalid." Rather, they believe in building confidence in models along multiple dimensions.[16] Peterson (1975, Appendix B) for example provides a list of thirty-five tests to which a system dynamics (or any) model can be subjected.[17] The more tests that a model can pass, the more confidence a system dynamicist has that the model can generate useful results that can be used to make an actual system perform better.

According to many system dynamicists one of the least powerful tests for building confidence in system dynamics models is fitting them to historical time series data.[18] As Professor Hayden correctly suggests, this activity often becomes an exercise in curve fitting that yields no new policy insights.[19] Indeed, no less a system dynamicist than Jay W. Forrester warns against this practice in system dynamics in general, and in system dynamics modeling of economic systems in particular:

> I believe there is much too much attention given in economics, and in system dynamics, to reproducing a specific historical time series. The dynamic character

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15 At the risk of stating the obvious, we are referring throughout this paper to instances of "proper" system dynamics modeling. It is unfair to use specific instances of improper system dynamics modeling put forth by unskilled (which typically means that they are untrained) modelers to criticize system dynamics in general. As in all fields of scholarly inquiry, instances of improper practice occasionally make it through the refereeing process.

16 There is an extensive literature on model validity and building confidence in system dynamics. See especially Peterson (1975, Appendix B), Forrester and Senge (1980), Radzicki (1988, 1990), Barlas (1989, 1996), and Sterman (2000, Chapter 21).

17 An especially clever test for building confidence in system dynamics models is called a "reality check." A reality check is performed by a software tool that enables a system dynamicist to run tests on a model that examine its robustness and conformity with the real world system. Reality checks have been shown to uncover important problems with models that were undetectable via traditional methods. See Peterson and Eberlein (1994).

18 See for example the discussions in Forrester and Senge (1980), Saeed (1992) and Radzicki (2004).

19 Unfortunately, it is often necessary to fit models to historical time series data to convince policy makers (or journal referees) to accept (and implement) model-based results.

> of past behavior is very important, but the specific values at exact points in historical time are not. Different random sequences in the past in the real economy would have produced different historical data sequences all with the same general character, just as would happen in a series of model simulations using different random inputs. Forrester (2003, p. 5)

Pushing the preceding point further, Forrester argues that system dynamics modeling produces a much richer form of economic analysis:

> After a talk at a joint NATO/US conference on cities in Indianapolis, Indiana in 1971, William Dietel, now recently retired as president of the Rockefeller Brothers Fund, came up from the audience to discuss their future programs. From that meeting came initial funding for our work in applying system dynamics to behavior of economic systems…The approach is very different from the conventional econometric models, which are structured on the basis of macroeconomic theory with parameters drawn from statistical analysis of historical data and with a heavy dependence on exogenous time-series to drive the dynamics of the model. From the system dynamics point of view, econometric models are essentially curve-fitting exercises. They do not contain the essential feedback structures that create the kinds of dynamic changes that are seen in real economies. Forrester (1992, p. 20)

To be fair, some system dynamicists disagree with Forrester and spend a great deal of their time fitting their models to historical time series data. However, unlike Professor Hayden's assertions, their models adhere to <u>both</u> good system dynamics modeling practice and good statistical theory [Radzicki (2004)]. According to Homer (1997, 293):

> Some system dynamics models are more effective than others in changing the thinking and actions of their audiences. In my experience, the models that prove most compelling to clients generally have two things in common: a potent stock and flow structure and a rich fabric of numerical data for calibrating that structure. Stock and flow structures focus attention on the intrinsic momentum of a situation and allow one to track movements of people and things in a clear and systematic way. Numerical data not only help to build a client's confidence in a model, but can also materially affect the final structure and key parameter values of a model.

Sector Diagrams & Causal Loop Diagrams

The final area in which Professor Hayden criticizes the application of system dynamics to institutional analysis involves what he calls "the unique conceptualizations in the Forrester tradition" (532). He writes that:

> Jay Forrester developed his analysis for electrical engineering systems and applied it, along with the positive and negative charges of electricity, to social science problems,…(533)

This statement is factually incorrect and actually quite ridiculous. Forrester originally developed system dynamics solely for the purpose of improving policy making by managers of corporations.[20] He never applied "positive and negative charges of electricity to social science problems" and, indeed, we're hard-pressed to understand what Professor Hayden is talking about when he makes this assertion.

Hayden then continues:

> Within most Forrester dynamics programs, there is the capability to attach any two entities in a program mapping and "tweak" the real or imagined connections with plus or minus charges to indicate influence, or support, or opposition, or causes, or whatever (534).

Again, this statement is filled with misunderstandings and inaccuracies. First of all, system dynamics software packages do not allow "any two entities" to be attached, willy-nilly. All system dynamics software packages contain rules that govern the proper attachment of icons on a computer screen – i.e., rules that govern proper equation writing and model construction. Second, a properly trained system dynamicist would never add "imagined" connections to a model of an actual system. Indeed, Forrester and Senge (1980, 212) write that:

> Verifying structure means comparing structure of a model directly with structure of the real system the model represents. To pass the structure-verification test, the model structure must not contradict knowledge about the structure of the real system.

Hayden next criticizes a figure taken from a paper by Thomassin and Cloutier (2004, 499), in which they appear to present a first-cut causal loop (influence) diagram representing important aspects of the Canadian hog production system. Our interpretation is that this figure represents the authors' initial efforts to conceptualize the system from a feedback perspective and does not represent their final results. Indeed, from what they say at the end of their paper (501) it appears that Thomassin and Cloutier intend to extend their work by building an actual

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20 See Forrester (1991).

system dynamics model.[21] If this is the correct interpretation of Thomassin and Cloutier's figure we have no particular objection to its presentation, as many system dynamicists utilize causal loop diagramming for brainstorming. Of course, a causal loop diagram is not itself a system dynamics model and, although some system dynamicists use this technique at the initial stages of a modeling effort, many do not:

> I do not use causal loops as the beginning point for model conceptualization. Instead, I start from identifying the system [stocks] and later develop the flow rates that cause those [stocks] to change. Sometimes I use causal loops for explanation after a model has been created and studied. For a brief overview presentation to people who will not be trying to understand the real sources of dynamic behavior, causal loops can be a useful vehicle for creating a general overall impression of the subject. Forrester (1994, pp. 252-253)

In sum, it appears that Professor Hayden doesn't understand that causal loop diagrams and sector diagrams are merely tools for conceptualizing and/or summarizing system dynamics models and that they are not, in and of themselves, system dynamics models.[22] Moreover, it appears that he is confused about the plus and minus signs that often appear at the heads of arrows in causal loop and sector diagrams. These signs do not represent electrical charges but simply mean "same direction" (plus sign) and "opposite direction" (minus sign).[23] Technically, each arrow ("causal link") connecting two variables in a causal loop diagram signifies cause and effect. A plus (minus) sign at the head of an arrow signifies that a change in the variable at the tail of the arrow causes a change in the variable at the head of the arrow in the same (opposite) direction, ceteris paribus. Mathematically, a causal link is thus a picture of a partial derivative.[24]

Examples of Best Practice

Perhaps the biggest problem we have with Professor Hayden's paper is that he has chosen to support his harsh criticisms of the use of system dynamics in institutional analysis by pointing to examples that are not system

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21 For a classic system dynamics modeling study of hog (and other commodity) production see Meadows (1970).

22 For a detailed analysis of the strengths and weaknesses of causal loop diagrams see Richardson (1986, 1997).

23 Instead of a plus and minus sign, many system dynamicists use an "S" and an "O" to designate "same" and "opposite."

24 Although there are exceptions. See Sterman (2000, Chapter 5, Especially pp. 139-141) for a discussion.

dynamics models, represent the initial stages of a system dynamics modeling study (not the final results), and/or do not represent the highest standards of system dynamics modeling. He ignores, for example, work such as Saeed's (2004) excellent study of the design of mitigation baking systems, Pavlov's cutting edge work on the dynamics of illegal file sharing over the internet (2005), Pavlov et al's (2005) work on instabilities in a superpower dominated economic system, and Nichols et al's. (2006) model of administered pricing, all of which has recently appeared in this journal. Moreover, he ignores other examples of excellent system dynamics practice that institutional economists would most likely find quite interesting such as Homer's (1987) analysis of the adoption and diffusion of new medical technologies, Homer's (1993) study of the supply of and demand for cocaine in the United States, Fiddaman's (2002) model of the economics of climate change, and Luna-Reyes et al. (2006) work on group model building via case studies. Coupled with Hayden's clear failure to learn about the proper way to conduct a system dynamics study,[25] this strikes us as extremely sloppy scholarship. To be honest, we would expect more from a Veblen-Commons Award winner.

Conclusions

Our analysis of Professor Gregory Hayden's objections to the use of system dynamics in institutional analysis has led us to conclude that they stem from both a misunderstanding of the details of proper system dynamics modeling and a failure to examine exemplary examples of system dynamics research. This is unfortunate because much of this information has been published in the pages of this journal. We hope that our comments will help to set the record straight and will inspire other heterodox economists to consider using system dynamics, where appropriate, for institutional analysis.

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[25] See Radzicki (2003).

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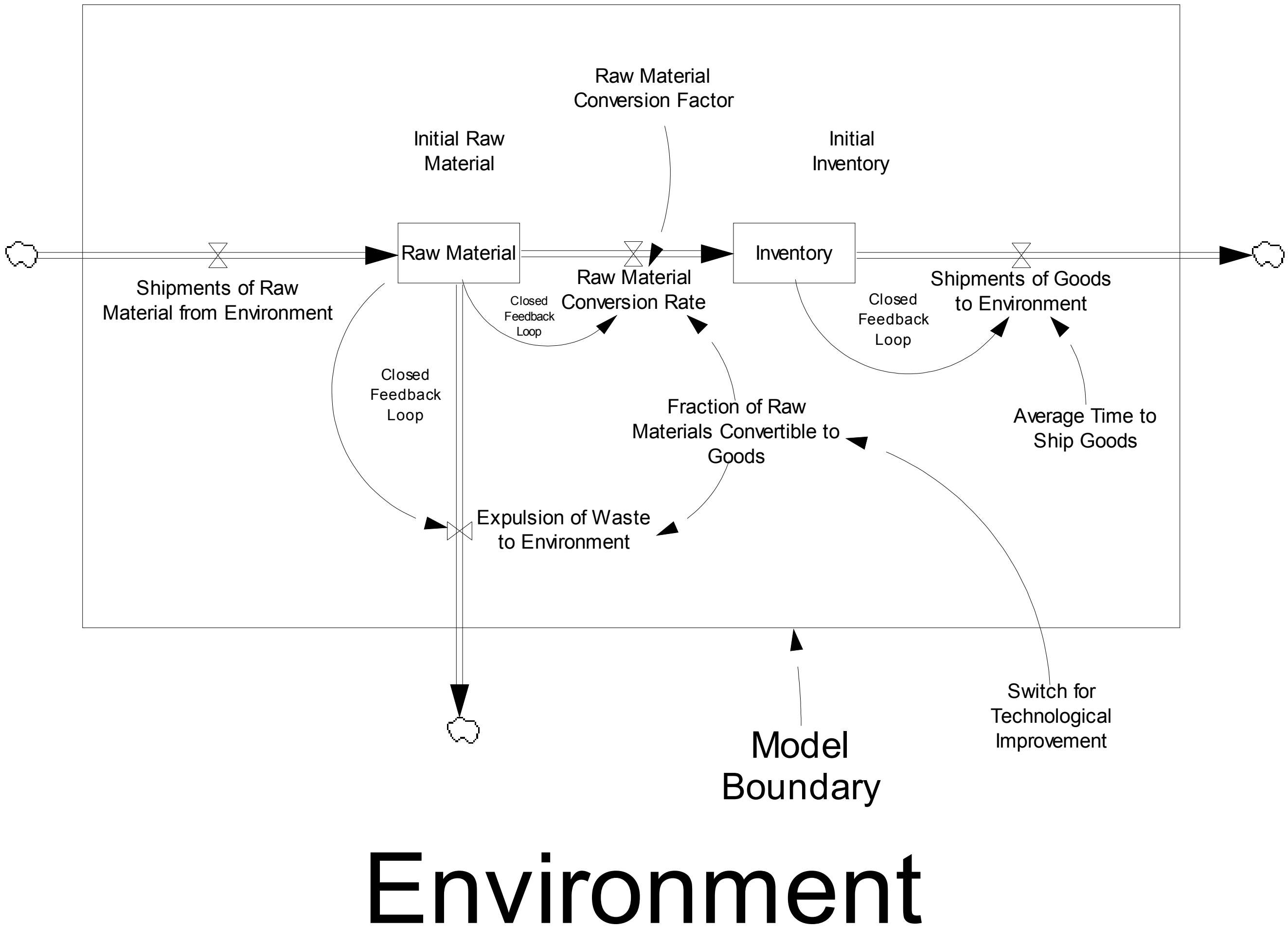

Raw Material = INTEG (+Shipments of Raw Material from Environment - Expulsion of Waste to Environment-Raw Material Conversion Rate \ Initial Raw Material) {Pounds}
Expulsion of Waste to Environment = Raw Material * (1 - Fraction of Raw Materials Convertible to Goods) {Pounds / Month}
Average Time to Ship Goods = 2 {Months}
Fraction of Raw Materials Convertible to Goods = 0.9 + Switch for Technological Improvement * Step(0.05, 1) {1 / Months}
Initial Inventory = INITIAL(Raw Material Conversion Rate * Average Time to Ship Goods) {Widgets}
Initial Raw Material = INITIAL(Shipments of Raw Material from Environment / Raw Material Conversion Factor) {Pounds}
Inventory = INTEG (Raw Material Conversion Rate-Shipments of Goods to Environment, Initial Inventory) {Widgets}
Raw Material Conversion Factor = 1 {Widgets / Pound}
Raw Material Conversion Rate = Raw Material * Fraction of Raw Materials Convertible to Goods * Raw Material Conversion Factor {Widgets /Month}
Shipments of Goods to Environment = Inventory / Average Time to Ship Goods {Widgets / Month}
Shipments of Raw Material from Environment = 1000 {Pounds / Month}
Switch for Technological Improvement = 1 {Dmnl}
FINAL TIME = 10 {Months}
INITIAL TIME = 0 {Months}
TIME STEP = 0.125 {Months}

Figure 1: Simple System Dynamics Model of an “Open” System the Receives Inputs from, and Expels Outputs to, its Environment

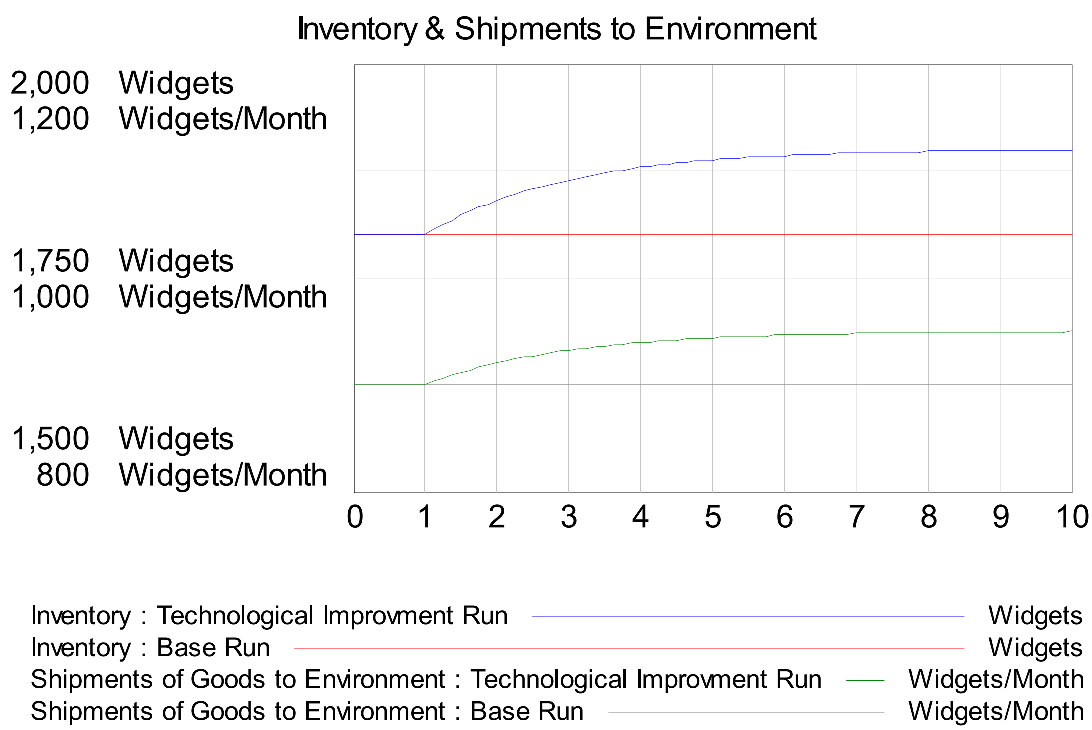

Figure 2: Two Simulations of the Simple System Dynamics Model of an "Open" System