Economic Issues, Vol. 5, Part 2, 2000

An Alternative Pedagogy for Economic Modelling

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Abstract
There is an awareness amongst teachers of economic modelling that new teaching methodologies and pedagogies are needed. This paper examines the weaknesses of traditional teaching methods and suggests that System Dynamics would be a useful supplement to the learning process for typical economics undergraduates. A brief description is given of the key features of the System Dynamics methodology and an illustrative example has been chosen. This is the multiplier-accelerator model of Samuelson. The System Dynamics approach is compared with more traditional approaches and several pedagogical points are emphasised.

1. Introduction

THIS paper offers a brief introduction to the methodology of System Dynamics and argues that this methodology offers pedagogical advantages in the teaching of economic modelling. Some economic reference point is needed to illustrate our case. We have chosen the multiplier-accelerator interaction first proposed by Samuelson (1939). Here, there is the possibility of chaotic behaviour developing due to switches in government policy or tiny exogenous or endogenous shocks, providing an excellent backdrop for the application of System Dynamics. Periodic macroeconomic instabilities are usually analysed by economists applying Keynesian, neoclassical or new classical theories, where the mathematical implications may quickly become intractable. An advantage of the new methodology is that the same level of analysis can be performed with little detailed knowledge of the mathematics required.

2. The case for a new methodology

Economic modelling is an important part of economics degrees and we focus on teaching in this area. Economic models often rely on complicated mathematics and especially advanced statistical techniques, for example, to analyse time series. For many students the mathematics is a barrier to their economic understanding. It is true that good software, such as MICROFIT, exists that can automatically perform all the statistical tests and resultant analysis but there is a great danger that if the student does not understand the limits and boundaries of the mathematical and statistical techniques then grave errors can be made. Another facet of these models is that, *ceteribus paribus*, they are static in the sense that if conditions change, the models have to be reformulated and a new time series examined. There have been a number of criticisms, typified by Lucas (1976), which question the theoretical foundations of the large structural models built in the 1950's and 60's. In econometrics, these arguments moved researchers away from reliance on structural equation systems for forecasting towards greater use of vector auto regressive models (Greene, 1997). Another common assumption is that if conditions were perfect an ideal equilibrium state would exist where, say, supply would actually equal demand and inflation would not exist. 'As long as we do not know with certainty where the economic forces will bring us in the long run, it cannot be methodologically legitimate just to presume that in the long run, the general equilibrium position is the relevant benchmark in macroeconomics' (Jesperson 1998).

'Most macroeconomics texts are obsessed with the idea that every "sensible" macromodel must define a full employment or natural unemployment solution. This perspective seems to be part and parcel of the landscape of the Newtonian conception of science.' (Clower 1988). To expand Clower's point, mathematics, as taught in schools and universities, is primarily that of linear dynamic systems of the type postulated and studied by Newton in the late seventeenth century. The mathematical ideas of Newton were taken up by other disciplines and the concepts of deterministic behaviour and stable equilibria were born. The Universe was a perfect machine - it existed in equilibrium - action equalled reaction. If one knew the correct laws to apply to a situation then one could correctly predict future behaviour.

This view has been under severe attack since the early 1900's - first by Relativity, then by Quantum Theory and recently by Dissapative Systems (Prigogine, 1985). The prevailing view is that the world is non-linear and exists in far from equilibrium conditions. The Holy Grail of a perfect equilibrium will never be found. Order can arise out of disorder. Chaos lurks round every corner. Deterministic equations do not necessarily lead to predictable results.

Applying these ideas to economics teaching, one sees that new methodologies are perhaps needed (Kemp 1997). Whatever methodology is chosen, it must be capable of easily incorporating non-linearity, delays and lags, feedback phenomena and chaotic behaviour. There would also be advantages if it were dynamic and constructive in the sense that the users actively build their own models rather than passively incorporating 'economic orthodoxies'.

> The object of our analysis is, not to provide a machine, or method of blind manipulation, which will furnish an infallible answer, but to provide ourselves with an organised and orderly method of thinking out particular problems: and, after we have reached a provisional conclusion by isolating the complicating factors one by one, we have then to go back on ourselves and allow, as well as we can, for the probable interactions of the factors among themselves. This is the nature of economic thinking. (Keynes 1936)

There is a continuing debate amongst educationalists as to the balance between how much students are taught and how much they are encouraged to think for themselves (Illich 1971, Richmond 1993, Moscardini 2000). We support pedagogies where students have the opportunity to build their own models, experiment with them, make mistakes and discuss their results under the supervision of their tutors. Such an approach encourages the use of divergent, holistic thinking rather than convergent reductionism. It also provides the opportunity to answer questions such as 'What if?' Time spent analysing past data may be of no relevance to the present time because of the accelerating nature of change. Dynamic models can reveal much more but have been hampered by the scarcity of good interactive software. The current development of such modelling tools, especially in the general area of Systems Dynamics, has provided the means to overcome these problems.

According to Richmond (*ibid*), if one switches to Systems Thinking then there are at least seven more fruitful types of thinking available. He classifies these as Dynamic, Closed loop, Generic, Structural, Operational, Continuum and Scientific Thinking. Each of these terms has a specific meaning but the common threads are:

i) the notion of modelling structure;
ii) the notion that it is the structure that causes behaviour;
iii) the ability to observe the effects of

changing parameters on behaviour of systems.

System Dynamics provides a methodology for doing this and software such as STELLA, VENSIM and POWERSIM offer the perfect platform for posing and answering 'what if?' questions.

A second issue is that there has been a revolution in thinking due to the recent advances in Chaos Theory. More and more fields of research are being affected. It is now becoming accepted that we live in a non-linear world and that simple models can generate complicated behaviour. There is no need for models with 200 variables and 200 equations, which take 24 hours to run and require mountains of precise data. Models using three or four variables with real-time delays can provide similar behavioural output but with the advantage of being able to predict 'much from little' (to use Friedman's dictum.) Economics teaching at undergraduate level should respond to these issues.

Increasingly, economics has been taught not as a way of learning to think about how the world might operate but as a set of discovered truths as to how the world does operate (Ormerod, 1995). The content of degree courses is becoming increasingly standardised. Substantial and impressive textbooks exist, both in micro- and macroeconomics, but these consist in the main of the mathematical techniques of the differential calculus applied to a model, which is a linear system. Economic forecasts have a poor record and many of the fundamental postulates are being called into question as some economists seek to restore the link with reality, which characterises the work of classical economists. (Ormerod, *ibid*). That this trend is widespread in Anglo-Saxon economics stems from several factors, which are summarised as:

- mainstream micro- and macro-theory is still premised largely on the derivation of equilibrium conditions for firms, industries and markets, either within partial or general equilibrium frameworks;
- states of equilibrium are examined on a comparative-static basis because of the mathematical convenience of the Marshallian approach;
- the intrinsic belief of most neoclassical theorists that economics, markets and industries always achieve equilibrium in the long run. Economics teaching should focus on the issue of 'training the mind' of students, following Sraffa's famous dictum in 1926 where ironically in this famous paper, Sraffa demonstrates that the Laws of Returns are incompatible with static equilibrium (Sraffa 1926);
- the schizophrenic Keynesian thinking of developing dynamic theories and testing them with static models;
- The continued reliance of theorists in developing computable General Equilibrium Models which develop static criteria for the existence of market clearing vectors at micro- and macro- levels;
- an intrinsic fear of developing non-linear models. This makes prediction less certain and marks economics as an underdeveloped science.

In this context, economics teaching needs new pedagogies and System Dynamics is being proposed as one that has great potential in this area.

3. Systems dynamic modelling

Dynamic macroeconomic models are useful in the policy formulation process. If such a model has faithfully replicated past behaviour, it yields confidence that it can predict possible future behaviour. Such models can be used to experiment with various economic policies without harming the actual economy. Many such models exist and are widely used. There are, however, intrinsically several disadvantages, for example:

- Many use branches of mathematics that are not understood by the politicians or economists who make the decisions;

- They are based on rigid assumptions which may or may not mirror the situation in the country to be modelled. This is especially true when key endogenous variables are non-observable, for example after privatisation has occurred in former highly labour intensive activities (Schmalensee 1988);
- they do not handle time lags very well without reliance on very limited initial conditions and the absence of random shocks;
- the people that build and run the models are not the decision-makers; hence there is a knowledge gap between the modellers and the practitioners. Sometimes, assumptions are not explicitly stated. Models may therefore be employed for other purposes than those that were originally intended. This is dangerous and can lead to the misuse and misapplication of the models.

Our objective in this paper is to show how modelling using System Dynamics can help to overcome these problems, in particular when linked to interactive, user-friendly, software. The methodology chosen was created by Jay Forrester at MIT in the 1950's to model social and business problems. If one asks most people a 'what causes what' type of question, one is likely to get a list of causal factors in response. The mental modelling process that produces these lists is termed laundry list thinking (Richmond 1993). Implicit in this thinking are:

1. Each factor contributes as a cause to the effect i.e. causality runs one way;
2. Each factor acts independently;
3. The weighting of each factor is fixed.

The System Dynamics methodology uses closed-loop thinking as opposed to laundry list thinking. Inherent in closed-loop thinking is causal reasoning and the presence of feedback. These are two key concepts in Systems Dynamics and need to be elaborated further.

Causal reasoning is shown by the construction of causal loop or influence diagrams which are shown in figures 1,2, and 3. The basic elements of such diagrams are positive and negative feedback loops.

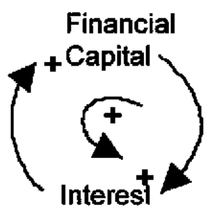

Figure 1: Example of a simple positive feedback loop

As an example, consider financial capital in a bank which will be augmented by interest payments and diminished by taxes. More financial capital produces more interest which in turn produces more financial capital. This can be represented diagrammatically by figure 1. The plus sign at the end of the arrow indicates that (all other things being equal) the quantity at the end of the arrow moves in the same direction as the quantity at the beginning. The arrow itself indicates the causality. The curved arrow enclosing a sign in the centre of the loop indicates the orientation of the loop. In this case it shows a positive feedback loop.

Taxes will have a diminishing effect leading to the diagram shown in figure 2. Here the minus sign indicates that an increase in Taxes diminishes the financial capital i.e. the two quantities move in opposite directions. The negative sign in the centre indicates a negative feedback loop.

In general, the orientation of the loop can be obtained by multiplying together the individual signs. Positive loops represent exponential behaviour and negative loops have a balancing role. A basic premise of System Dynamics is that all processes are combinations of positive and negative feedback loops.

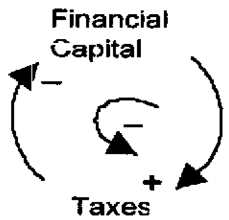

Figure 2: A Negative feedback loop

A simple economic example is shown in figure 3. One can follow the causal reasoning via the arrows. As this is a positive loop, one could deduce that in the long run, aggregate demand would grow indefinitely in the absence of any external or internal constraints.

An increase in production leads to an increase in Aggregate Supply. In conventional terms, this moves along the Aggregate Demand curve, leading to a rise in expenditure and income. Higher income generates increased savings, which (via conventional neoclassical reasoning) leads to increased investment and further production. Hence, figure 3 represents a model of exponential expansion. Since this does not typify the behaviour of most modern economies, we are led to re-examine some of the assumptions built into the model. Alert students might question, for example, whether an increase in savings (which, *ceteris paribus*, implies a reduction in consumer's spending) would necessarily lead to an increase in investment.

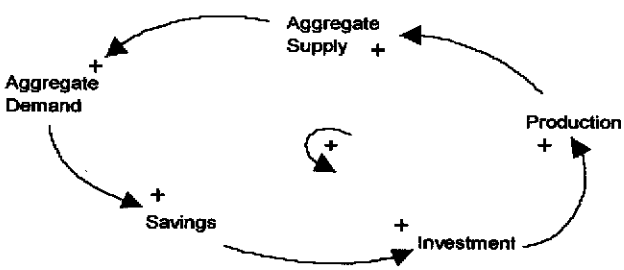

Figure 3: An economic example

Influence diagrams can be of value in their own right - often indicating the long-term behaviour of a system. This will obviously depend on the relative strengths of the various loops but it enables one to say, for example, 'if this loop is dominant then the system will settle down' or 'if this loop is dominant then the system will expand'. A major tenet of Systems Dynamics is that structure determines behaviour. If the structure of an economic situation is modelled correctly then its behaviour will be captured.

Once an influence diagram is agreed upon, then a Systems Dynamics model can be constructed. Such models use the two concepts of 'stock' and 'flow'. Stock is a quantity that is accumulated. These stocks have inflows and outflows. This structure is stylised so that the rectangles represent stocks and spigots represent flows. Constants are represented by a diamond shape. New software products that have been produced over the years allow the model to be built and represented in a form that can easily be understood by non-mathematicians. For example the influence diagram in figure 1 would be represented by the system dynamics model in figure 4.

A further advantage is that the software then automatically generates equations, an example of which is shown below:

init	Financial Capital = 0
stock	Financial Capital = +dt*interest
flow	Interest = Financial Capital*interest_rate
const	interest_rate = 0.2

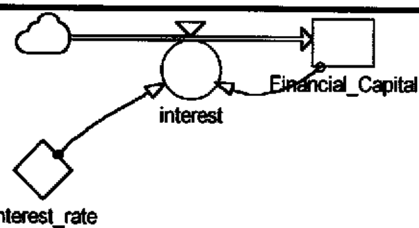

Figure 4: A system dynamics model

These equations correspond to first-order, non-linear, difference equations. The equations above are the POWERSIM form of the equation:

$$C_t = C_{t-\Delta t} + \Delta I_t \quad \text{where } C_0 = 0$$

and where C represents financial capital and I represents the interest rate.

They are automatically solved by the software (using the Runge-Kutta method) with no expertise needed by the user. The equations state the initial condition for the financial capital (i.e. zero) and the fact that is augmented over time by the flow of interest. The interest is calculated by multiplying the financial capital by the interest rate, which is set at 0.2. It is an easy mathematical task to change this to a first order differential equation thus giving an entry into mathematics if desired.

Another advantage of such software is that it can deal with 'softer variables' i.e. variables that have a qualitative or human aspect such as motivation, trends and collective actions. It does this by providing the option of a graphical function to define relationships between variables. To illustrate this option, let us return to the situation described in figure 4 and assume that the interest rate is not constant but is reviewed each month by the Monetary Policy Committee of the Bank of England. A major factor in their decision is their judgement of how inflation will behave. This could be modelled in the following manner. The probability of rising inflation could be crudely estimated as low, medium or high and this will result in changes of -¼%, 0 or +¼% in the base rate. Figure 5 shows how this can be modelled as a graph. The x-axis represents their estimate of the probability of rising inflation. 'Low' is modelled as between 0 and 0.3, 'medium' between 0.3 and 0.7 and 'high' between 0.7 and 1.0. The rise in base rate is modelled as a step function. The modified System Dynamics diagram is shown in figure 6. Here the circle entitled interest_increase' containing a jagged line indicates that the relationship is a graphical one.

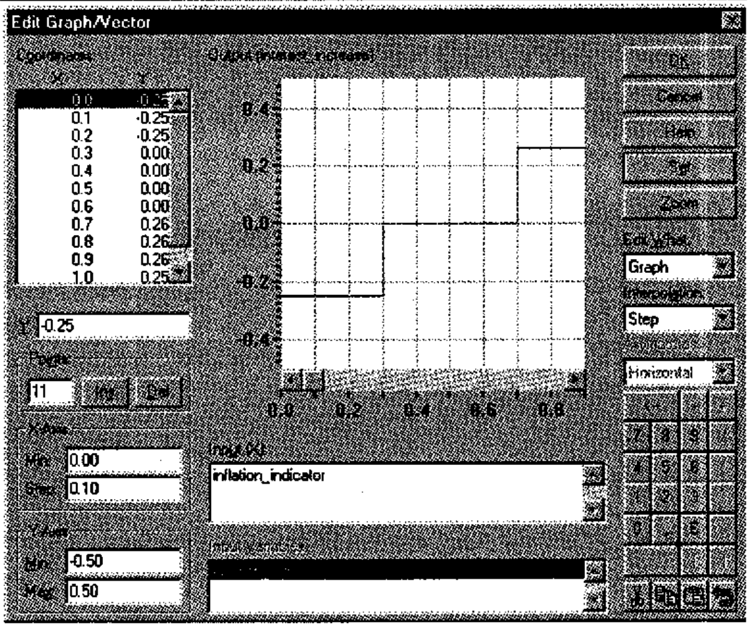

Figure 5: A graphical relationship

Here the Monetary Policy Committee's expectation is set under the variable named 'Inflation_ Indicator' and this will result in the appropriate action taken on the base rate. The purpose of this rather crude example is simply to show the power of the software not to illustrate economic fundamentals.

The most widely used software is STELLA which has a business version called 'ITHINK' (Richmond 1987). VENSIM (Peterson and Eberlein, 1994) has an extra feature which does validity checks. The models in this paper are built using POWERSIM. This software is created by the Powersim Corporation, USA-Norway (Powersim Manual, 1996).

The power of this new computer-based methodology is not that it is more accurate than more orthodox models but that the modellers and the practitioners can work together. It is ideal for capturing intellectual models and for establishing implications. Key economic constructs and new ideas can be introduced into these models and simulated with real-world data. It is especially good in modelling 'soft scenarios' where the data is not precise. Normalised trends can be entered in the form of a graph and thus the modelling can proceed.

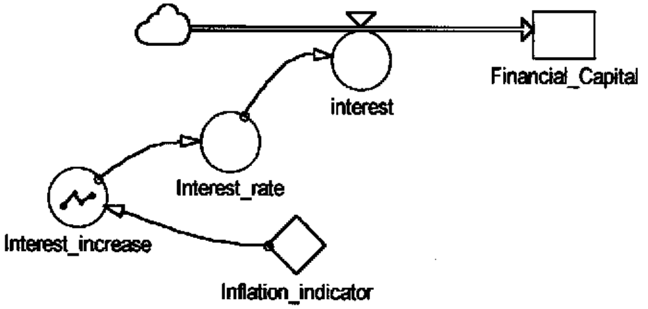

Figure 6: The modified diagram

4. An Economic model investigated

4.1 Choice of Model

We choose to investigate the accelerator-multiplier interaction of Samuelson (*ibid*). This is a classic situation where the effects of a change in investment spending can be initiated by an increase in autonomous expenditure. In the simple equilibrium model an increase in investment leads to a larger increase in aggregate demand and income. As income increases, there are further increases in consumers' spending, leading to even further increases in aggregate demand and income. This is the multiplier.

If there is an initial change in investment, then this may set off a chain reaction between the accelerator and the multiplier. Hence if there is a rise in autonomous expenditure, this will lead to a multiplied rise in income. However, this rise in aggregate income (demand) kick-starts the accelerator effect: firms respond to the rise in aggregate demand by increasing investment. This rise in investment constitutes a further rise in aggregate demand (income). If this increase in income is larger than the preceding rise in income, there will be further increases in investment (the accelerator) which in turn causes another rise in income (the multiplier). This process may proceed indefinitely. Each time investment changes, income changes and each time income changes this also changes investment. However, this does not lead to an explosive rise in income. There are two potential reasons for this. Firstly, national income cannot go on rising faster than the growth in potential output. Income expansion will be constrained by the ceiling of full employment of labour or other resources, though this is an additional constraint, not built into Samuelson's simple multiplier-accelerator model. The second reason why the accelerator/multiplier does not lead to ever rising income is that if investment is to go on increasing indefinitely, it is not enough that income should be rising: instead income would have to rise *faster and faster*. Hence once income growth slows, investment must fall and the whole process is reversed. Clearly, the accelerator/multiplier interaction is sufficient to cause cyclical upswings and downswings.

Figure 7 is an explanatory diagram for the multiplier-accelerator effect exactly as it is in a popular economic text (Sloman 1997). Here, *J*, *I* and *Y* represent injections, investment and aggregate demand (income). We contend that the explanation given here is not entirely clear.

Another common form of representing this model is to combine Samuelson's original equations to give the second order difference equation:

$$y_t = a + by_{t-1} + cy_{t-2}$$

period t	J ↑ → Y ↑	(multiplier)
period t+1	Y ↑ → I ↑	(accelerator)
	I ↑ → Y ↑	(multiplier)
period t+2	If $\uparrow Y_{t+1} > \uparrow Y$ then I ↑ OR If $\uparrow Y_{t+1} = \uparrow Y$ then I stays same (accelerator) OR If $\uparrow Y_{t+1} < \uparrow Y$ then I ↓ This is turn will have a multiplied upward effect no effect or a multiplied downward effect respectively on National Income	
period t+3	this leads to further accelerator effects or otherwise	

Figure 7: Explanation of the accelerator-multiplier interaction

This has three main solutions: regular, damped and unstable oscillations depending on the choice of parameters for the multiplier and the accelerator.

4.2 A Systems Dynamic approach

The novel approach in economics teaching we are advocating is for students to construct their own mental models of the situation using influence diagrams and System Dynamic models as shown in figures 8 and 9.

Figure 8 depicts a typical causal diagram built to capture the essential elements of the multiplier-accelerator model augmented by a monetary sector. It depicts an interpretation of the flow of funds and the circular flow of income. Causal models are qualitative. It is not important at this stage that the terms used are absolutely precise. Meanings have to be debated and agreed before the transfer to the System Dynamics model. The flow of funds/income around the circular flow captures the relationships between wages, employment and income. Savings and taxes drain and investment and consumption enhance this flow. If the profitability of firms increases, investment and employment increase with delays causing increases in income and consumption. This effect of increased investment resulting in increased income and consumption models the multiplier effect. The effect of consumption on induced investment models the effect of the accelerator.

Valuable insights can be gained by students building such simple representations. It can be seen from the diagram that there are three positive feedback loops balanced by three negative loops. Depending on the various strengths of these loops, classical equilibrium or positive growth / decay can be expected. By building such models, concepts such as delays and exponential smoothing cease being dry mathematical constructs but take on real meanings

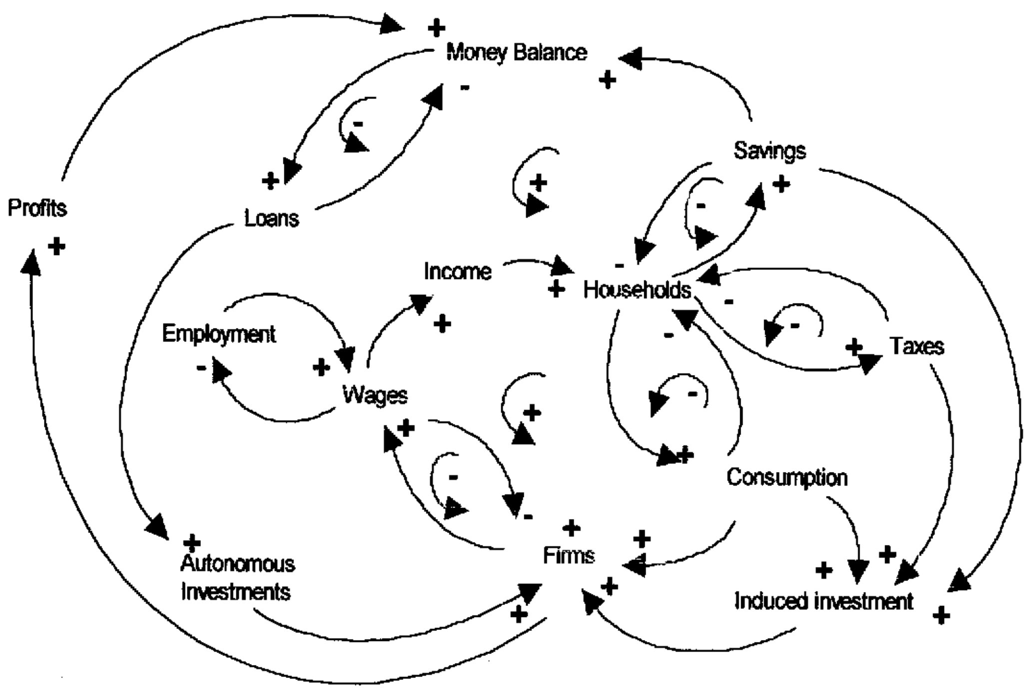

Figure 8: A causal representation of the accelerator-multiplier model

and relevance. The pedagogical advantage of this approach is that the students are using their own economic logic to build models under the guidance of the lecturer. By doing so, they are learning how factors influence each other and about the whole picture of interdependencies. They have abandoned the laundry-list and are thinking dynamically. If the models are incorrect or inappropriate then this can be pointed out, the issues discussed and another valuable learning experience gained.

Figure 9 shows how the qualitative model has been made into a quantitative Systems Dynamics model. Note that all the terms have not remained the same and extra terms have had to be added (such as mpc, marginal propensity to consume) in order to enable the causal links. The qualitative (causal) and the quantitative (System Dynamics) models are not isomorphic. In the diagram, delays are represented by arrows which are marked with small parallel lines and the delayed variable is represented by a partially filled rectangle. To enhance the visual effect, variables can be copied from one part of the diagram to another. Such copies are shown by circles surrounded by the four corners of a rectangle. In this model, the mpc reflects the multiplier effect of increased consumption on income counterbalanced by the mps. The model captures withdrawals via savings and taxes. The multiplier-accelerator interaction is captured when an increase in government spending increases income, consumption and induced investment. The 'flow of funds' circulating throughout the economy is now modelled in more detail. It is falling with increases in mps and rising with increased mpc, ultimately leading to enhanced loan rates for investment and additional increases in income (accelerator).

This is, potentially, a great advance in the training of economics graduates, because to

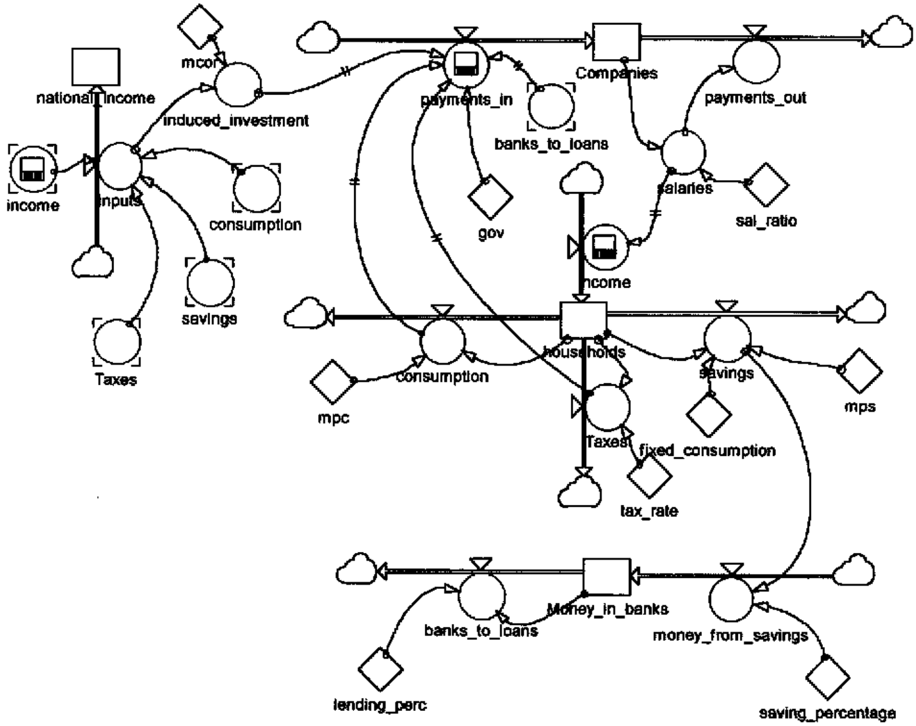

Figure 9: The system dynamic model

some extent, it links modern students to insights delivered in Keynes's *General Theory*. This famous text has been criticised over the years for developing a dynamic macro theory linked together with a system of static models. Hence, Keynes famous 'Notes on the Trade Cycle' in the *General Theory* are dynamic sets of insights and largely overlooked nowadays by textbook writers and theorists.

4.3 Simulation runs

In our model it is assumed that the accelerator lies between 0.8 and 1.1 and the marginal-propensity to consume is around 0.5, giving a multiplier of 2. Aggregate demand is boosted by government expenditure if there is spare capacity in the economy in the short run or cost cutting technology in the long run. There are various delays in the system:

i) a four week delay for payments of salaries;
ii) a four week delay for consumption to feedback into production;
iii) a twenty-six week delay for investments from loans to feed into production.

The models are run over a simulation time of twenty years using weekly intervals and using the Runge-Kutta fourth order solution option.

The paper presents three simulations.

1. The first corresponds to a classic textbook equilibrium. There are no delays or leakage in the system. The income circulates around the economy. The positive and negative loops balance each other. The student can experiment with various forms of government interventions and still observe how the equilibrium holds. POWERSIM provides tables which gives quantitative results as well as the graphical

form. A typical graph is shown in figure 10.

2. Figure 11 shows the results of a second simulation using the delays mentioned above and with various government expenditure boosts to the economy. The results show a damped cyclical pattern when delays are introduced but with a slightly larger multiplier of 2.6. The delays effectively curtail or suppress the impact of the accelerator. However, moving to figure 12 reveals the erratic nature of the cycles when the marginal propensity to consume and the delays are left constant but slightly higher values for the accelerator coefficient are introduced.

3. In the third model, the accelerator principle assumes that firms estimate future demand and profits by extrapolating past demand growth. This information governs their investment patterns. It can be seen that the behaviour of the economy becomes erratic. The model is extremely sensitive to small changes in the marginal capital output ratio, which indicates that chaos is lurking. This is a valuable experiment for students. One of the runs is shown in figure 12.

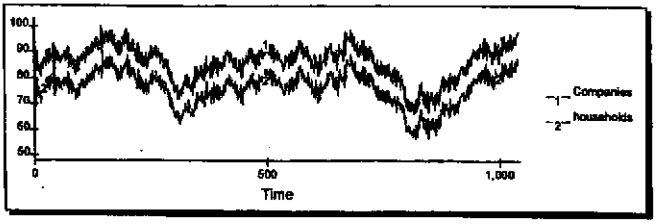

Figure 10: Classic equilibrium

This POWERSIM model is a simplification. A complete model of investment could allow for both the effects of changing aggregate demand on expected profits and the role of interest rate changes in altering present values of expected future profit streams. The model confirms that the accelerator is a useful simplification of the role of investment in economic cycles. The model here of the accelerator-multiplier interaction can generate cycle without limits and cause swings in aggregate demand. What are the constraints on the extent of the fluctuations shown in figure 12? The Samuelson multipli-

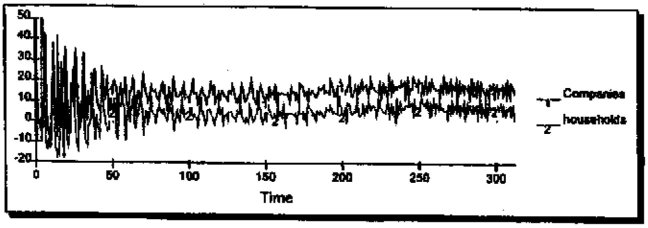

Figure 11: Dynamic equilibrium

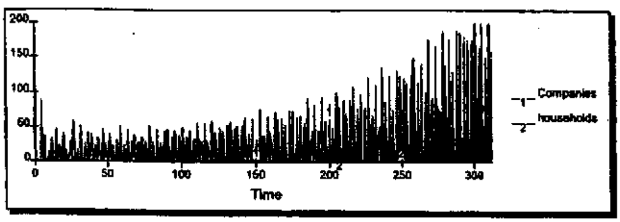

Figure 12: Potential chaos

er/accelerator interactions produce endogenous cyclical movements in the growth of the economy. The endogenous nature of these cycles show how cyclical patterns may be damped or explosive and indicate the potential for volatility in a market economy. However, Hicks (1950) showed that by introducing exogenous limits to growth like full employment (ceilings) and autonomous investment (floors) even explosive movements in growth may be trapped thereby reducing the potential volatility.

5. Conclusion

Economics teaching is currently experiencing several difficulties which have been discussed at length. The advantages of introducing a new methodology based on Systems Dynamics into the mainstream economic teaching have been outlined. Students are not just regurgitating economic theory but are actively debating the precise meanings of economic terms, building their own models of the economy and interactively experiencing successes and failures. The students are thinking as well as learning. It is hoped that concepts would become meaningful and the students eventually 'get a better feel ' for the subject. It is surprising how little of this type of work is done in UK undergraduate economics degrees.

The Samuelson model was chosen as a vehicle for demonstrating various strengths of the proposed methodology. These included qualitative modelling, graphical relationships, delays, quantitative modelling and simulation runs exploring 'what if' scenarios. The Systems Dynamics approach clearly reveals an area of potential chaos. Most governments rely on official data to operate their fiscal stabilisation programmes. Naturally this builds in large information delays, recognition lags and eventual implementation lags. When government expenditure is a significant component of aggregate demand, chaotic movements in aggregate supply and demand are likely. The privatisation process too includes a lag vis-à-vis implementation. Hence government expenditure is likely to exacerbate booms and intensify slumps (Blejar and Skreb1997).

These economic insights square with the observations made by famous economists and politicians over the years. Thus in 1958 Harold Macmillan made the famous observation in a parliamentary debate that 'choosing optimal strategies to govern the country is like looking up today's trains in last year's timetable.' This observation merely echoed a powerful plea made 150 years ago by the theorist Simon de Sismondi (1827):

> Let us beware of the dangerous theory of equilibrium which is supposed to be automatically established. A certain kind of equilibrium, it is true, is re-established in the long run but it is only after a frightful amount of suffering.

Endnotes

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