Using System Dynamic's methodology to teach Macroeconomics

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Abstract

Teaching Economics largely involves the use of comparative static models relying on regression analysis for empirical verification. The purpose of this paper is to show that by using influence diagrams and causal loop simulations to teach macroeconomics, there are definite pedagogical advantages to be gained and it is hoped that more of these methods will be adopted by economics teachers in the future. As a vehicle for illustrating these methods, this paper investigates a model of the circular flow of income including the market of the factors of production, as well as injections and withdrawals. Advantages of the systems approach are demonstrated which bridge the gap between understanding the structure and understanding the behaviour of an economic system.

1. Introduction

> *"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 about 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."*

This quote from Maynard Keynes [1] although intended to describe the study of economics could equally describe System Dynamics. One problem with Economics teaching at the undergraduate level is that it does not follow Keynes' ideas. It is 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. Substantial and impressive textbooks exist, both in micro- and macro-economics, consisting in the main of the mathematical techniques of the differential calculus applied to linear systems but very little of these texts are true in the sense that statements in a textbook in say engineering are true. Because of this, economic forecasts have a very poor record and many of the fundamental postulates are currently being called into question as some economists seek to restore the link with reality which characterises the work of classical economists. The purpose of this paper is to demonstrate that by using System Dynamics many of these difficulties can be overcome.

The paper first examines different ways of thinking and shows that systems thinking and its attendant software is good for economics. An example is selected and discussed before the conclusions are stated.

2. Modes of thinking and modelling

2.1 Linear Thinking and Static Modelling

Linear thinking is best exemplified by mathematics where the mathematical solution always follows logically step by step. The equation contains certain parameters, which have already determined the problem. Once the equation is written, then the solution is fixed. This type of reasoning is essential for precision modelling such as in designing and building electronic components but has problems when trying to cope with 'softer' problems such as economic ones.

Richmond (1993) defines a mode of thing called 'laundry list' thinking. By this is meant the kind of thinking that produces lists of independent factors or answers that can be ticked as on a laundry list. E.g. the answer to the question "what affects the quantity demanded from a commodity" would be a list of independent factors " price of the commodity it self, price of substitute goods, price of complementary goods, income, taste …etc). Much of economic teaching uses this type of thinking which in our opinion is not optimal.

According to Richmond (1993) the implicit assumptions in the laundry list thinking process are:

1. Each factor contributes as a cause to the result and the causality runs one way.
2. The factors act independently
3. If the factors are weighted , the weighting is fixed
4. The factors have either a positive or a negative influence

This way of thinking tends to lead (if we are trying to model it) to static reductionist models. Such models might describe a system mathematically in terms of equations, where the potential effect of each alternative is ascertained by a single computation of the equation. The variables used in the computations are averaged, assumed to act independently and the usual way of dealing with them is by fitting a curve or some regression technique. The performance of the system is determined by summing their individual effects. Balance sheets are an example of static models

Static Models ignore time based variances. They are not good in determining the impact of something that occurs in relation to another incidence. Also, they do not take in account the synergy of the components of a system, where the action of separate elements can have a different effect on the total system than the sum of their individual effects would indicate

One can understand each part of the system but still not understand what the system is.

2.2 Systems Thinking

System thinking suggests opposite views to laundry list thinking

1. The causes are linked in circular processes (feedback loops), i.e. the causalty runs both ways.
2. There is interdependance between the factors as causes are linked in a circular process to each other and the result.
3. In circular causility the strength of the loops vary over time, some loops will starts as dominant, others will take over in time . so there is no fixed weighting.
4. In system thinking, a correlation between a factor and the effect is not enough , it is nessesary to have an operational explanation to how the effect is generated

Another facet of System thinking is that it enables one to model holistically, i.e, look at the whole system. There are many examples of solutions that have not worked because they only treat part of a system and do not consider the whole (Wolstenholme 1990). Because factors are interdependant, their effects cannot be ignored. This leads to problems defining boundaries as theoretically , everything should be included, and then the system will become too large to model. There is thus a skill involved here, and it is the structure of a system that is regarded as significant for the behaviour over time that should be included (Forrester, 1961),but the fact that System Thinking is aware of the problem is a major advance on previous modes of thinking.

This thread of thinking leads to system dynamics modelling. In order to carry out a system dynamics analysis a model of a system is first design (dynamic models on a computer), and thereafter the model is used as a vehicle for carrying out experiments. The purpose of these “what if” experiments is to understand and assess how the real system performs, and thereafter predict the effects over time of changes in the system. By a system dynamics model it is meant a simulation model that react to, and reflect the structural changes in a real world system. Such structural changes are typically changes in the dominance of the various circular causal relationships, as well as changes in the effects of time delays and non-linear relationships between elements in the model. The structural changes will again give rise to behavioural changes in these models.

Dynamic modelling can predict the outcomes of possible courses of action and can account for the effects of variances or randomness. That doesn't mean that we can control the occurrence or random events. It means that we can use dynamic modelling to predict the likelihood for a set of occurrences, and thereafter assess their consequences. Dynamic models can reveal much more compared to static models, but the widespread use of dynamic models have been hampered by the scarcity of good interactive software. The current development of such modelling tools, especially in the field of systems dynamics, have provided the means to overcome this problem.

3. The Economic Example

3.1 Traditional Approach

The choice was to investigate the Circular flow of income as depicted by Sloman (1997). His model is depicted in figure I and is an example of a static model. The consumer of goods and services are labelled "Household", the member of the household are the providers of the factors of production, such as land, labour… etc. The producers of goods and services are labelled 'firms'.

Firms and Household are in a twin demand and supply relationship with each other. Firms exchange goods and services for money so money flows form household to firms in the form of consumer expenditure, and house hold exchanges factors of production for money which flows in the form of income There is thus a circular flow of income, household earns income from firms and firms earn income from household, the money circulates, there is a also a circular flow of goods and services but in the opposite direction.

The flow diagram can help to show the distinction between microeconomics and macroeconomics. Microeconomics is concerned with the composition of the circular flow while macroeconomics is concerned with the total size of the flow, and what causes it to expand and contract. If household spends all their incomes on buying domestic goods and services, and if firms pay out all this income they receive as factor payment to domestic households, and if the velocity of circulation does not change, the flow will continue at the same level indefinitely, i.e. the money just goes round and round at the same speed and income remains the same.

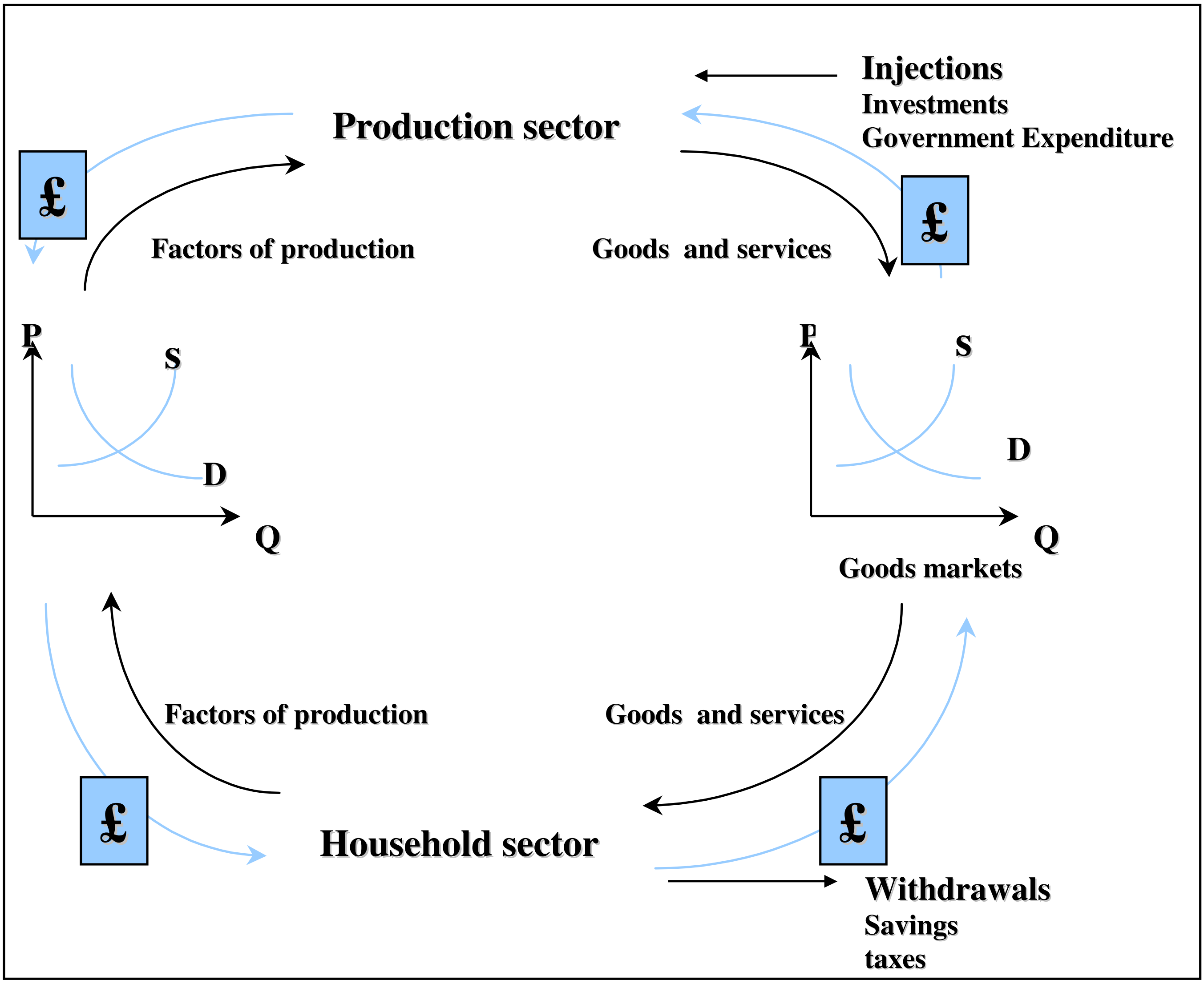

Figure 1

On the left-hand side of the diagram money flows directly from firms to household as 'factors payments', and on the right hand side household pays money to firms in the same country. There is then an inner circular flow of payments from firms to household to firms and so on. This flow is shown in figure one but it is entirely a pictorial static depiction. Time is not shown explicitly in the diagrams and although the student can see a general picture it would be difficult to answer a what-if problem. Other disadvantages of such a diagram in teaching the students is that there is no iteration, the students can't see the interdependence of the variables, and it also doesn't explain to the student how the system works

3.2 System Dynamic Approach

3.2.1 Causal Model

A new approach in teaching economics is to let the students build their own understanding of the problem by using influence diagrams. A typical influence diagram for the flow of income in an economy as defined by Sloman is shown in figure 2. Causal thinking can provide valuable gains, because it forces the students to think about the structure of the problem studied, and it makes them see dependencies easier. In addition, being forced to build causal diagrams themselves, the student will be active and not passive towards the diagrams. As it is acting at a higher level of recursion the student does not need to become involved in the details of the cause and effect mechanisms in order to allows for a holistic picture to be assembled. This diagram shows 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.

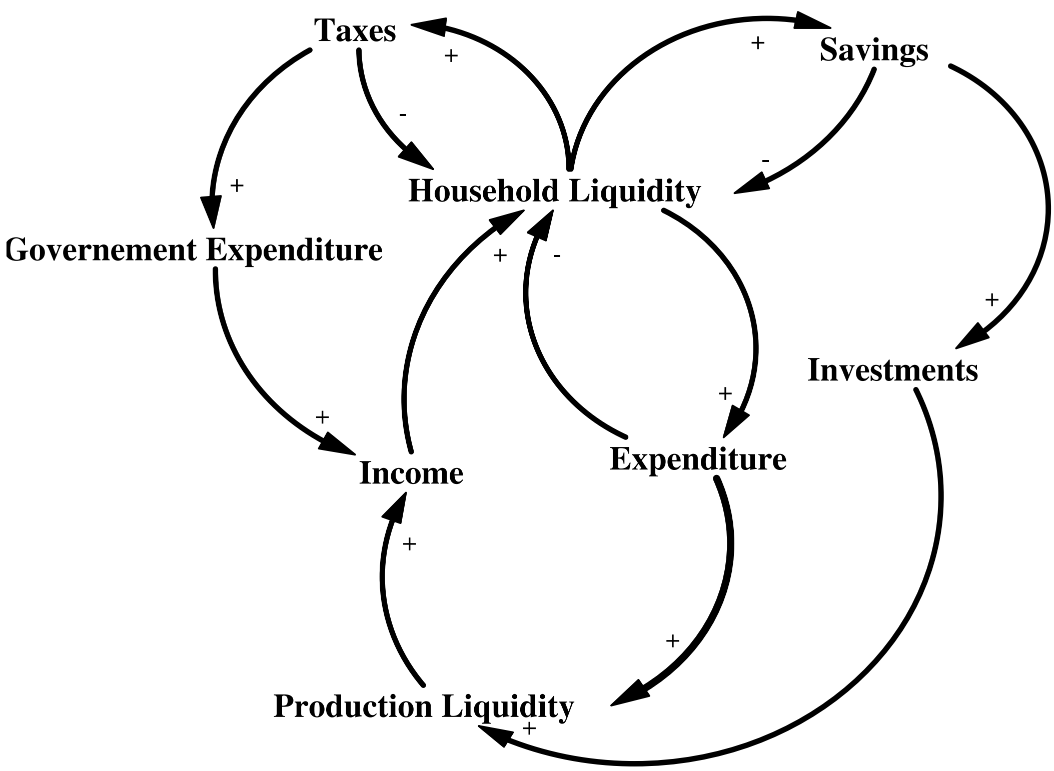

Figure 2 Causal Model

This aspect illustrates an important feature of such models – long term and short-term behaviour. Behaviour is determined by the structure of the model so understanding structure is an important part of understanding behaviour.

Causal Models can be constructed at different levels. On the left hand of the diagram in figure , there are markets. the causal diagram in figure 3 shows one of the factors of production markets in more details

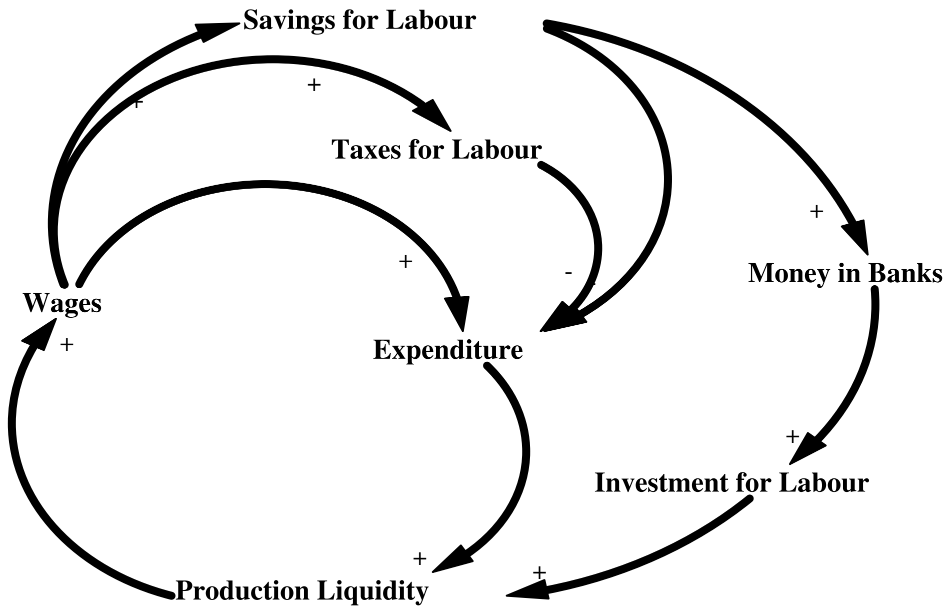

Figure 3 Labour Market

3.2.2 System Dynamics Model

The causal models shown above are still static models, they are not able to derive the dynamic implications of the structure that is pictured. The beauty of the approach we are advocating is that these can now be adapted to produce system dynamics models, which can replicate the behaviour over time. When the behaviour over time is simulated, a tool for comparing the long-term and the short-term behaviour of the system is found . Behaviour is determined by the structure of the model so understanding structure is an important part of understanding behaviour. Because of the powerful software now available, the building of a systems dynamics model from the causal loop is often dismissed as routine but it can be difficult even for experienced modellers. A typical model is shown in figure 7.

It consists of a main model that shows the dynamic flow of income in an economy from the household sector to the production sector in the form of Expenditure and from the production sector to the house hold sector in the form income .

Income is payment for the factors of production owned by the household sector and is modelled by four separate models i.e. (Labour, Land, Capital and Organisation markets models)

The Bank sector is modelled separately. It shows the Savings cycle which is considered withdrawals from the flow until it is injected again in the form of Investments . Also , the Government sector is modelled separately as it shows the Tax cycle which is also considered a withdrawal from the flow . until it is injected again in the form of Investments

In constructing this model, it was realised that there is a causal link between expenditure and investment which was not shown in figure 1, 2 and 3. This in fact is the accelerator which is the subject of another chapter in Sloman's book. New causal loop was then produced. This shows the iterated nature of the modelling process which is distinct from the linear approach in Sloman's book.

By running such a model, the student can gain valuable insight into delays and exponential smoothing. These concepts cease being dry mathematical constructs but take on real meanings and relevance. The pedagogical advantages in this approach is that if students are using such models, they are learning how factors influence each other and about the whole picture. They have abandoned the laundry list and are thinking dynamically - maybe for the first time in their lives!

Students need not build models at first, it is enough to use models under different circumstances and see the consequences. They can then experience the short term and long term behaviour anticipated in the causal loops

A more sophisticated model can be built using control levers so that a student can change the conditions that the flow relies on and observe the change in behaviour .In this model levers were introduced for:

1. Marginal Propensity to Save, MPS (applied in every market independently) which is the proportion of an increase in national income saved , $MPS = \Delta S / \Delta Y$
2. Taxes percentage applied in every marker independently, i.e. taxes for labour, capital, land , Organisation
3. Levers to alter the delay period between withdrawals (taxes, savings) and injections (government expenditure, investments).
4. Adjustable table function for the Marginal Propensity to Invest as this depends on the expectations of businessmen.

The student can by these levers neutralise the affect of the withdrawals and injection and there for her can see the equilibrium straight line that is discussed before as the inner flow loop. By introducing the withdrawals and there for injections to the income flow, as well as the delays the student can see the dynamic equilibrium that is represented in Figure 4

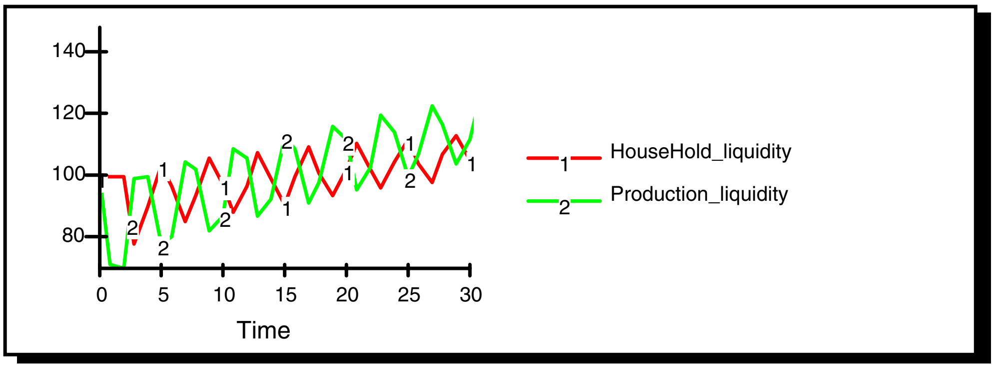

Figure 4 Dynamic Equilibrium.

The representation of all factors of production makes it easy for students to plot the behaviour of any market as they change the particular levers that control the savings and consumption behaviour of the markets. They can also observe the effect that increasing government taxes on a particular market has on the market itself and on the performance on the whole income flow in a closed economy.

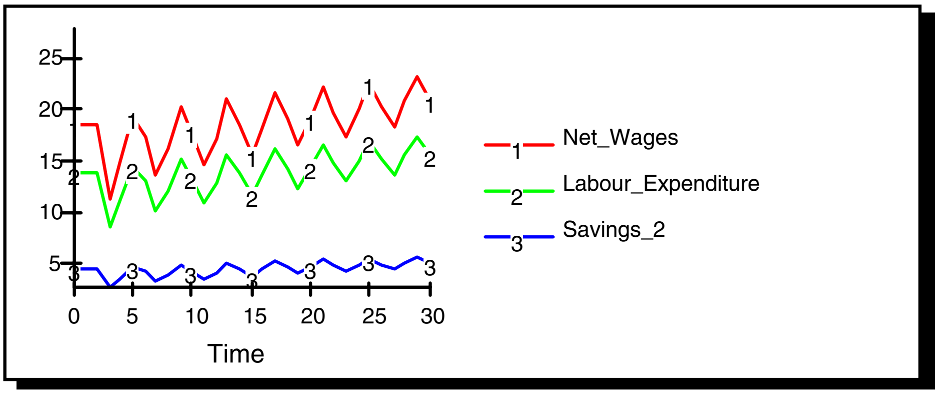

Figure 5 Change in Savings

The savings represented by the curve 3, also the difference between curve 1 and 2 in figure 5, could be changed in the labour market separately using the MPS lever and watching the effect on the income and expenditure behaviour

Using also the levers that control the banking sector, the bank strategic reserve limit and the government sector delays which is increased in case of bureaucracy and hidden unemployment makes the student get the feeling of how the whole economy works.

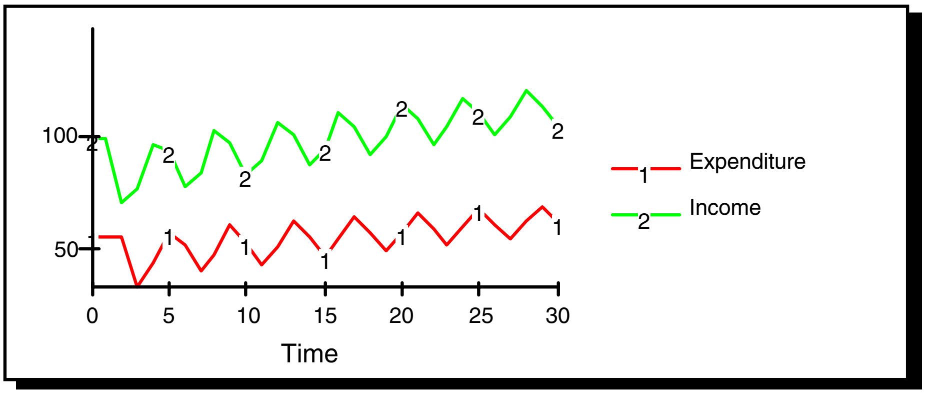

Figure 6 Change in Withdrawals

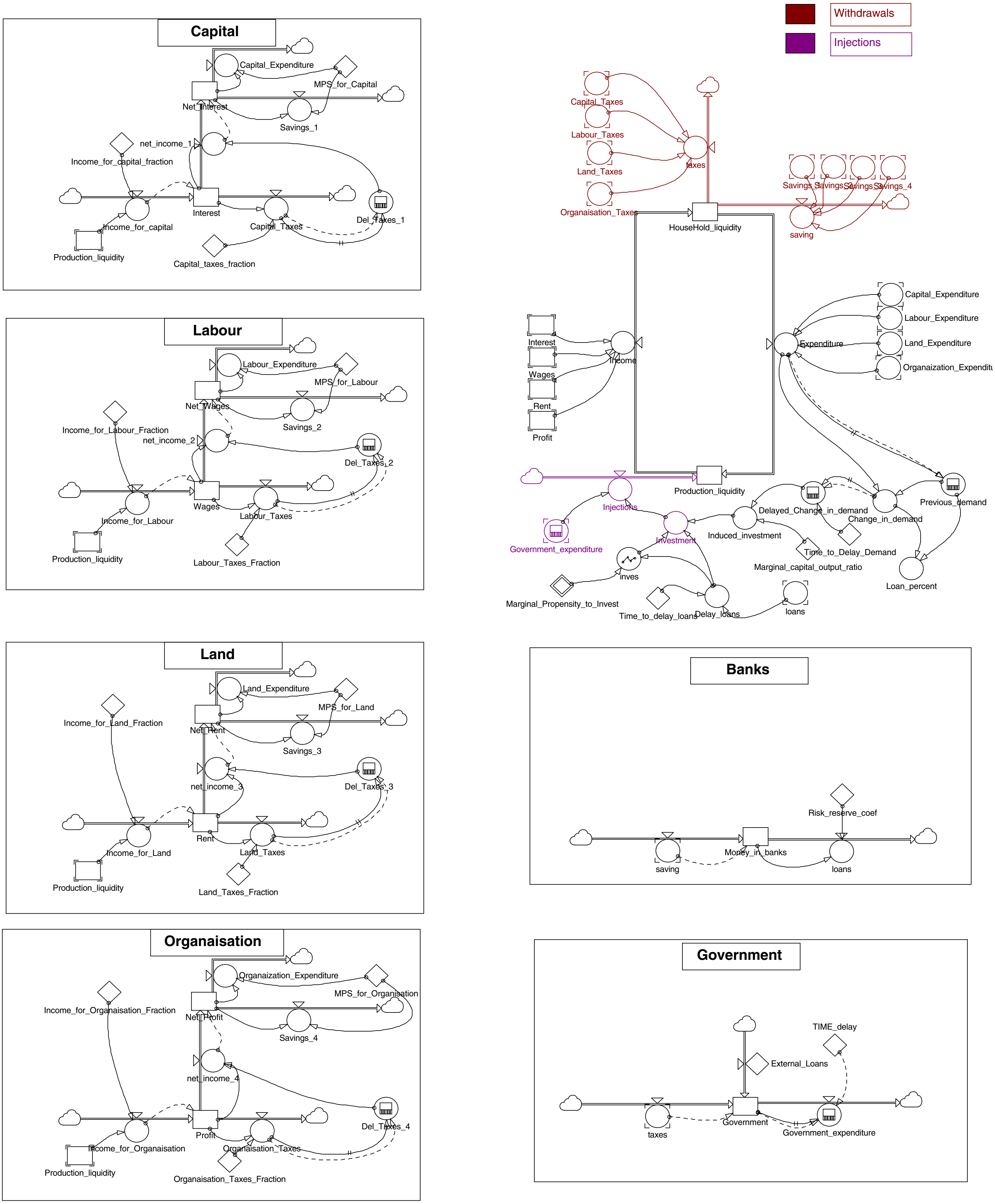
Withdrawals
Injections
Capital
Capital_Expenditure
MPS_for_Capital
Net_Interest
Savings_1
net_income_1
Income_for_capital_fraction
Interest
Capital_Taxes
Del_Taxes_1
Income_for_capital
Production_liquidity
Capital_taxes_fraction
Labour
Labour_Expenditure
MPS_for_Labour
Net_Wages
Savings_2
Income_for_Labour_Fraction
net_income_2
Del_Taxes_2
Wages
Labour_Taxes
Income_for_Labour
Production_liquidity
Labour_Taxes_Fraction
Land
Land_Expenditure
MPS_for_Land
Income_for_Land_Fraction
Net_Rent
Savings_3
net_income_3
Del_Taxes_3
Rent
Land_Taxes
Income_for_Land
Production_liquidity
Land_Taxes_Fraction
Organaisation
Organaization_Expenditure
MPS_for_Organisation
Income_for_Organaisation_Fraction
Net_Profit
Savings_4
net_income_4
Del_Taxes_4
Profit
Organaisation_Taxes
Income_for_Organaisation
Production_liquidity
Organaisation_Taxes_Fraction
Capital_Taxes
Labour_Taxes
Land_Taxes
taxes
Organaisation_Taxes
HouseHold_liquidity
Savings_1
Savings_2
Savings_3
Savings_4
saving
Capital_Expenditure
Labour_Expenditure
Land_Expenditure
Organaization_Expenditure
Expenditure
Interest
Wages
Rent
Profit
Income
Production_liquidity
Injections
Government_expenditure
Investment
Induced_investment
Delayed_Change_in_demand
Change_in_demand
Previous_demand
Time_to_Delay_Demand
Marginal_capital_output_ratio
Loan_percent
inves
Marginal_Propensity_to_Invest
Time_to_delay_loans
Delay_loans
loans
Banks
Risk_reserve_coef
saving
Money_in_banks
loans
Government
TIME_delay
External_Loans
taxes
Government
Government_expenditure

Figure 7

Conclusions

Textbooks in economics provide the students with static snapshots of the real world, but they are usually not able to communicate the time dimension of the models of the economy. The advantages of introducing this system dynamics methodology into the mainstream economic teaching are obvious. The student will then not just regurgitating dry economic theory, but will actively interact with models of the economy and experiencing the effect of changing the withdrawals and the injections to an income flow model using levers and table functions. The student can now answer to himself the question "what if". The student is thinking as well as learning. Concepts become meaningful and the students eventually "get a feel" for the subject. It is surprising how little of this type of work is done in the UK at the undergraduate level.

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