Old Wine in a New Bottle: Towards a Common Language for Post-Keynesian Macroeconomics Model

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Stock Flow Consistent methodology provide a common ground for the Post Keynesian Economics. System dynamics became a natural tool for solving simultaneous differential or difference equations or structural equations model. This paper aims for pedagogical and didactic approach by showing how to refactor a simplified stock flow consistent model into a component based system dynamics model. By using hierarchical component based modeling approach, the model result would be easy to understand and to communicate.

Keywords: system dynamics, difference equations, differential equations, post-Keynesian, stock flow consistent, modeling framework.

Chapter 1: Introduction

"I have found out what economics is; it is the science of confusing stocks with flows". A verbal statement by Michal Kalecki, circa 1936, as cited by Joan Robinson,in 'Shedding darkness', Cambridge Journal of Economics,6(3), September 1982,295–6.

There are two big paradigms in economics. On the one hand there is the mainstream, or neo-classical, paradigm, which is based on the premise that economic activity is exclusively motivated by the aspirations of individual agents. On the other hand there is alternative paradigm, which has come to be called 'post-Keynesian' or 'structuralist'. It derives originally from those economists who were thinking that the system as a whole is closed in the sense that every flow and every stock variable is logically integrated into the accounting to such a degree that the value of anyone item is implied by the values of all the others taken together; this follows from the fact that every row and every column sums to zero. This last feature will prove very useful when we come to model behavior; for how ever large and complex the model, it must always be the case that one equation is redundant in the sense that it is implied by all the other equations taken together. (Godley and Lavoie, 2007)

The 'Global Financial Crisis' is widely acknowledged to be a tail event for neo classical economics, but it was an expected outcome for a range of non-neoclassical economists from the Austrian and post-Keynesian schools. There are only two of Bezemer's twelve individuals (Bezemer, 2009) that were guided by mathematical models to anticipate the GFC: Wynne Godley (Godley & Lavoie, 2007) and Steve Keen (Keen, 2007). The two contending mathematical approaches are therefore Godley's 'Stock-Flow Consistent' framework, and Keen's complex systems approach to Minsky's 'Financial Instability Hypothesis'.(Keen, 2013).

The modern industrial economies have a complex institutional structure comprising production firms, banks, governments and households and that the evolution of economies through time is dependent on the way in which these institutions take decisions and interact with one another. Our aspiration is to introduce a new way in which an understanding can be gained as to how these very complicated systems work as a whole. (Godley & Lavoie, 2007)

The financial system can be represented using a network accounting model, which reveals the values for all stocks and all flows in one integrated diagram that in an instant gives you an overall picture and forms part of the basis for intelligent and informed decision making (Thomsen, 2003). The accounting model approach of macroeconomic explicitly model financial sector as distinct from the real economy, so allowing for independent growth and contraction effects from finance on the economy. Model outcome or the stability in response to shocks and disturbances in macroeconomics environment and policy is determined by accounting identity not by equilibrium concept (Bezemer, 2010).

We believe that the methodology is system thinking that is based on system dynamics. System thinking requires us to construct model of the system before we draw conclusions or make decisions. System dynamics is an interdisciplinary thinking method that uses a powerful metaphor of a bathtub or water tank to model the state of the system in a time point and the change to that state over a time period. System dynamics is also used to study the behavior of complex systems based on the explicit representation of feedback loops. System dynamics also gives visual sense of the whole system picture that could be used to enhance understanding and to communicate effectively. The system dynamics perspective is an inward or endogenous point of view, because it believes that the cause of the system behavior comes from within the system not from external forces or outside the system.

Problem

The following problems are excerpt from (Kinsella, 2011):

The objective of stock flow modeling should be the ability to practically model unstable macro-economies, and in particular their interactions with the financial sector. The stock flow models also capture several important Keynesian and post-Keynesian insight. The nature of the complication of stock flow models is important: in addition to degrading one's eyesight with subscripts, writing out balance and transactions matrices serves to clarify for the modeler the exact set of hypothesized relationships between variables, and between sectors.

Stock flow consistent model share the same problem with system dynamics model. They have next to no grounding in empirical macroeconomics mostly designed as tools for thought experiments rather than practical tools to guide policy

Future work in this area should concentrate on three fronts. First, because of their inherent complicatedness we should establishing notational conventions and simplifications to increase the readability of stock flow models, and second, we need to expose them to empirical data as soon as possible using an estimation approach. Third, there needs to be a fuller appreciation of the delicacy of initial conditions and/or stock flow norms, taking more account of advances in behavioral, experimental, and computational economics, to provide more realistic layers for the sectors most stock flow models are built out of.

Scope & Methodology

Conceptual model in the form of casual loop diagram represents interaction between factors qualitatively. Causal loop diagrams are inherently weak because they do not distinguish between information flows and conserved (non-information) flows. As a result, they can blur direct causal relationships between flows and stocks. Further, it is impossible, in principle, to determine the behavior of a system solely from the polarity of its feedback loops, because stocks and flows create dynamic behavior, not feedback. Finally, since causal loop diagrams do not reveal a system's parameters, net rates, "hidden loops," or nonlinear relationships, their usefulness as a tool for predicting and understanding dynamic behavior is further weakened. (Radzi, 1997)

Building model is faster and easier when we are not doing it from scratch. Molecules are the LEGO from which good system dynamics models are built (Hines, 1996). It is like using object oriented approach in analysis or design patterns in software realm. Each of the molecules will be encapsulated in a module and can be assigned their own inputs, outputs and parameters. In component/object based modeling there are two ways to reuse, the first is composition and the second is inheritance. We use composition approach by encapsulating molecule in a module, and then reuse the module. The inheritance approach uses a different taxonomy of molecules than the composition approach used. The taxonomy is organized based on specialization hierarchy and provides path for model evolution. The inheritance approach constructs simulation models by successively replacing parts of predefined molecules with more specialized molecules (Malone, 2009). The paper gives an example of the approach in supply chain domain.

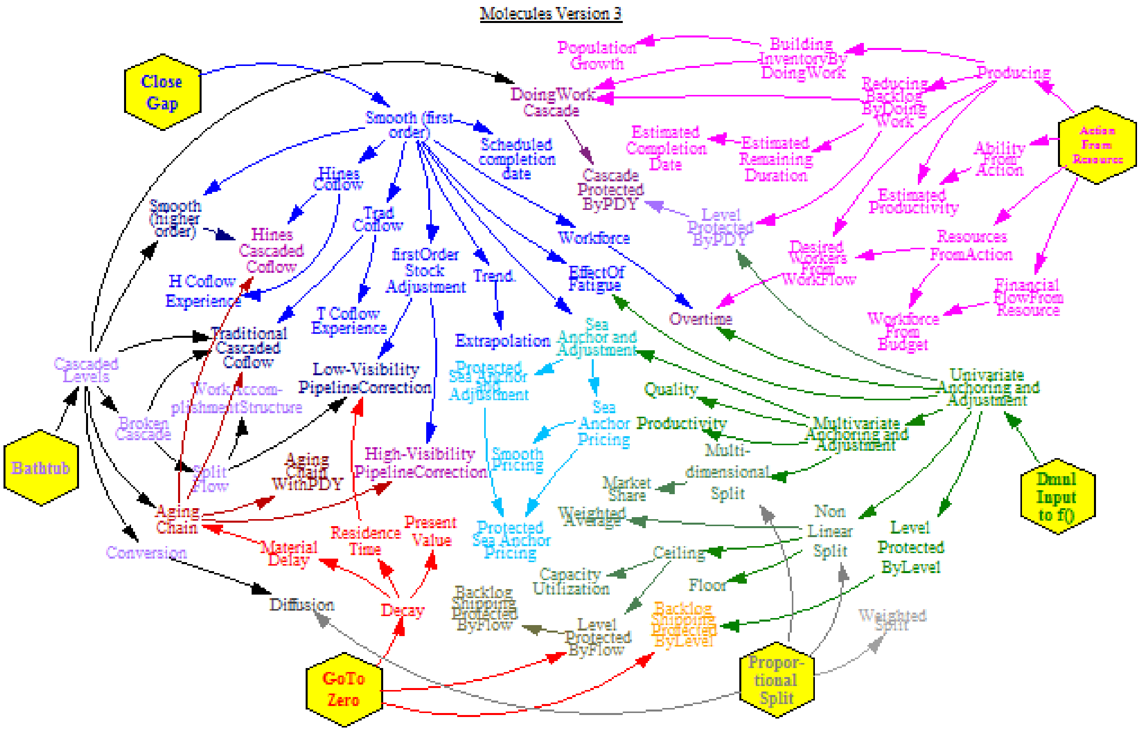

Figure 1. Molecules relationship map in Vensim software as a building block or a module

We already put the Keen's model which use differential equations in the previous paper (Utama, 2013). This paper extends and complements the previous paper by not just using differential equations but also static and difference equations. Causality modeling is inherent in stock flow thinking, because sum of flows caused change in stock and flows arise from differential equations (Hirsch, 1984). The resulting model should be hierarchical and component based. So we can zoom in or zoom out of the model and the components that have been created can be used for other modeling purposes.

Tools

For modeling and simulation tool, we use Simantics system dynamics tool (Lempinen et al, 2011). The tool is based on open source, so that the modeling software becomes more affordable and the distribution of models becomes easier. The tool used the open source OpenModelica environment to simulate the system dynamics models. The models are translated into Modelica language and OpenModelica is used to compile and simulate the Modelica code. The modeler doesn't have to understand the Modelica language. Modelica is an object-oriented, equation based modeling language that has originally been created for modeling and simulating physical systems (Fritzson, 2011). System dynamics models are basically just differential equations that can easily be represented in the Modelica language.

The object-oriented nature of the Modelica language provides a natural solution for the implementation of hierarchical modules. Adopting this type of object oriented approach to system dynamics modeling can significantly speed up the development of large and complex models. The modules clearly and logically separate different functionalities in the model. Reusing the created module is simply a matter of dragging another instance of the module to the diagram and defining the input and output variables.

Simantics System Dynamics runs under Java 6 (not Java 7) and can be downloaded for free from https://www.simantics.org/simantics/download
The documentation and the tutorials can be found in this page
https://www.simantics.org/end_user_wiki/index.php/Simantics_System_Dynamics

Chapter 2: Solving static, difference and differential equations with SD

SYSTEM THINKING

There are seven thinking tools/mode in system thinking (Utama, 2013)

1. Verbal model, describing the world using the words and narrative story. It is the most flexible also can be ambiguous because of the richness of a language.
2. Conceptual model, a form of visual map that represents concept and relationship between the concepts. The relationship modeled usually static and structural. Examples are data model, class diagram, and causal loop diagram.
3. Spreadsheet model or table/matrix model, usually in form of excel kind of spreadsheet
4. Operational model, which describes the dynamics and behavior of the system. Examples are system dynamics/stock-flow diagram, state diagram, petri net, and workflow.
5. Geometric model, it could be a simple graph describing behavior over time or relations between variables.
6. Mathematical model, takes form of equations, it could be algebraic equations or differential/difference equations.
7. Computer model, a program that will make the model executable by the computers

Mathematical model

Mathematical model of the graph in continuous time can be described with an algebraic equation such as:

$$Saving(t) = Saving_0 e^{rt}$$

where $Saving_0$ is the initial value of the saving account. We can also write it differently as a differential equation:

$$\frac{dSaving}{dt} = r * Saving$$

Or as recurrence relations/ recursive formula:

$$Saving(t) = Saving(t-1) * (1+r)$$

Or as a difference equation:

$$Saving(t) - Saving(t-1) = r * Saving(t-1)$$

SYSTEM DYNAMICS

Fundamental Law

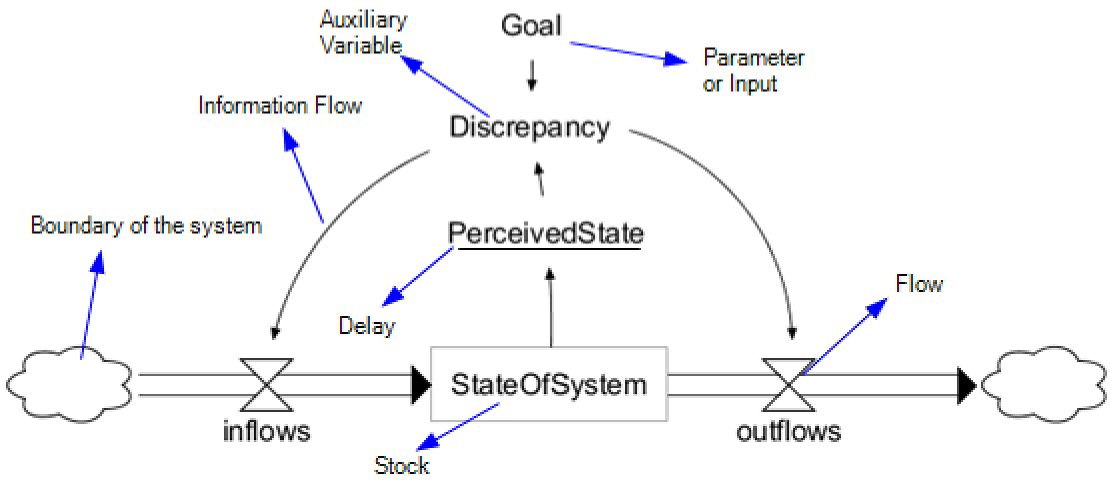

Figure 2. Building block of stock flow diagram

The equation that manages stock is

$$\frac{dS}{dt} = \sum(inflows - outflows)$$

The sum of inflows minus the sum of outflows equals to change of the stock level. By this equation alone we can convert one form to the other form. The principle is simple. The ordinary differential equations or difference equations can always transfer to stock flow diagram and vice versa. So we can read it as one another, whichever way is more comfortable. But SD diagram can convey 'information flow' nicely, while in the backstage it actually transforms into a full set of differential equations.

The order of the system is determined by the number of stocks in the system. Behavior of lower order system can be produced by the higher order system, e.g. behavior of zero order system can be produced by first order system or higher and patterns in first order system can be produced by another higher order system.

Chapter 3. Getting a Sense Post-Keynesian Modeling with System Dynamics

EVOLUTION OF KEEN-MINSKY MONETARY MODEL

Steve Keen built model of Minsky's FIH (1995) which displayed qualitative characteristics that matched the real macroeconomic and income-distributional outcomes of a period of economic volatility followed by a period of moderation, leading to a rise on instability once more and a serious economic crisis. He also built a strictly monetary macroeconomic model which can generate the monetary as well as the real phenomena manifested by both the Great Recession and the Great Moderation. The content of this section mainly extracted from his papers (Keen 1995, 2007a, 2007b, 2010a, 2010b, 2011a, 2011b) unless stated otherwise.

Simple endogenous money model

The core of the framework is a tabular layout of financial relations between the economic entities. The table is called "the Godley Table" to honor Wynne Godley. Each column in the table represents an aggregate bank account for a specific sector of the economy. Each row in the table represents financial transactions between those accounts or a particular economic activity. The model is explicitly monetary. The symbolic sum of the operations in each column generates rate of change for that account in terms of differential equations. The system of ordinary differential equation then can be analyzed and simulated using symbolic mathematical software.

The basic endogenous model is of a pure credit economy with only private banking and without government sector. The initial stock of endogenous money is created via a loan from the banking sector to the firm sector. This loan simultaneously creates a deposit of the same magnitude that enables the firm sector to hire workers to produce output. The economic flows generated in this system are:

1. The loan contract allows the bank to compound the outstanding debt;
2. The deposit receives interest from the bank;
3. The firm sector hires workers from the household sector;
4. Households receive interest payments from the banks; and
5. Households and banks purchase goods from the firm sector.

There is no repayment in this basic model. The flows are represented on a Godley table below:

Flow/Stock	**Firm Loan F_L**	**Firm Deposit F_D**	**Worker Deposit W_D**	**Banker Deposit B_D**
Lend Money (Initial value of stock)	+Loan	+Loan		
Charge Interest		-Interest Charge		+Interest Charge
Pay Firm Deposit Interest		+Firm Interest		-Firm Interest
Pay Worker Deposit Interest			+Worker Interest	+Worker Interest

Hire Workers		-Pay Workers	+Pay Workers	
Workers' Purchase		+Workers' Consumption	-Workers' Consumption	
Bankers' Purchase		+Bankers' Consumption		-Bankers' Consumption

Figure 3. A Godley table for basic endogenous model

The explanation of the flow and its substitution is described in the table below

Flow	**Expression**	**Description**	**Parameter values for simulation**
Interest Charge	$r_L \cdot F_L$	rate of interest on loans times debt level	$F_L(0) = F_D(0) = 100$ $W_D(0) = B_D(0) = 0$ $r_L = 5\%$ p.a $r_D = 3\%$ p.a $w = 3$ p.a $\beta = 0.5$ p.a $\omega = 26$ p.a Value of 26 for ω indicates that workers spend their wages every two weeks, so it is inverse time-lag / time constant. Time unit is year.
Firm Interest	$r_D \cdot F_D$	rate of interest on deposits times firm deposit level	
Worker Interest	$r_D \cdot W_D$	rate of interest on deposits times worker deposit level	
Wages	$w \cdot F_D$	rate of wage payment times firm deposit level	
Bankers Consumption	$\beta \cdot B_D$	rate of spending of bankers times banker deposit level	
Workers Consumption	$\omega \cdot W_D$	rate of spending of workers times worker deposit level	

Figure 4. Table of substitution and parameters for basic endogenous model

By summing the column (excluding the initial value of loan), we can write the differential equations of the system as:

$$\frac{d}{dt}F_L = 0$$

$$\frac{d}{dt}F_D = (r_D \cdot F_D - r_L \cdot F_L) - w \cdot F_D + (\omega \cdot W_D + \beta \cdot B_D)$$

$$\frac{d}{dt}B_D = (r_L \cdot F_L - r_D \cdot F_D) - r_D \cdot W_D - \beta \cdot B_D$$

$$\frac{d}{dt}W_D = w \cdot F_D + r_D \cdot W_D - \omega \cdot W_D$$

The ordinary differential equations can be represented in system dynamics approach as we can see from the preceding chapter. The accounts are converted into stocks while the financial transactions are converted into flows. All the parameters are converted into auxiliary variables. The differential equation or the accounting table can be translated into a stock flow diagram as depicted below

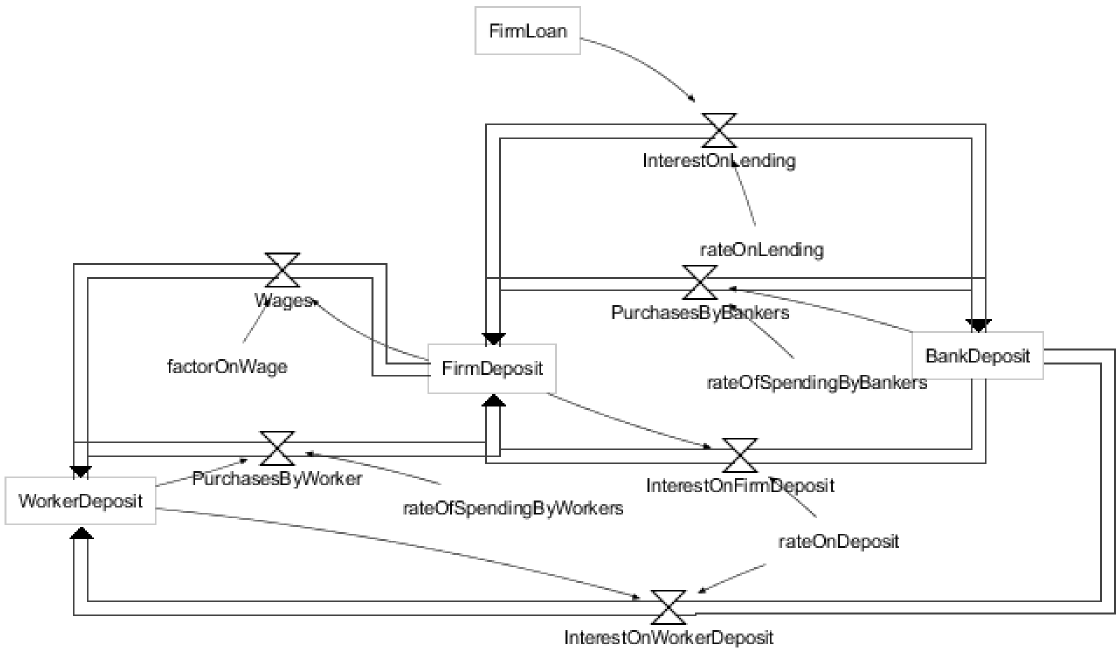

Figure 5. Stock flow diagram for basic endogenous model

The resulting behavior towards equilibrium can be seen in figure below:

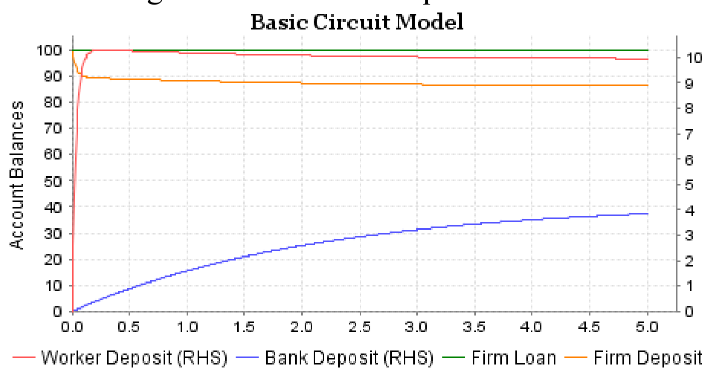

Figure 6. Behavior of basic endogenous model

Business cycle with Goodwin's model

Goodwin's model is a subclass of predator-prey model also known as the Lotka-Volterra model that we already discuss before. The predator-prey can be thought as analogy of class struggles between capitalists and workers. The cycle can be made from the following descriptions:

1. Level of output per annum Y is determined by level of capital stock K and accelerator v : $Y = \frac{K}{v}$
2. Level of employment L depends on level of output Y and labor productivity a : $L = \frac{Y}{a}$

3. Employment rate λ is ratio of labor L to population N : $\lambda = \frac{L}{N}$
4. Rate of change of real wages $\frac{dw}{dt}$ is determined by the wage rate w and employment rate λ via a linear Phillips curve : $\frac{dw}{dt} = (-c + d \cdot \lambda) \cdot w$ where c and d are coefficients of linear Phillips curve
5. Level of profit Π equals to output Y minus wage bill $W = w \cdot L$ which is wage rate times employment: $\Pi = Y - w \cdot L$
6. Profit Π determines investment I (in the simple Goodwin model, all profits are invested) : $I = \Pi$
7. Rate of change of capital stock $\frac{dK}{dt}$ equals to Investment I minus depreciation $\gamma \cdot K$, closing the model : $\frac{dK}{dt} = I - \gamma \cdot K$
8. Population N is determined by population growth β: $\frac{dN}{dt} = \beta \cdot N$
9. Labor productivity a is determined by labor productivity growth α : $\frac{da}{dt} = \alpha \cdot a$

The model consists of four differential equations in the real wage, capital stock, labor productivity, and population growth. The cycle was made by the closed loop feedback between stock of capital and wage stock.

Using system dynamics tool the information flow and dependency relation between variables can be seen clearly as shown in the figure below:

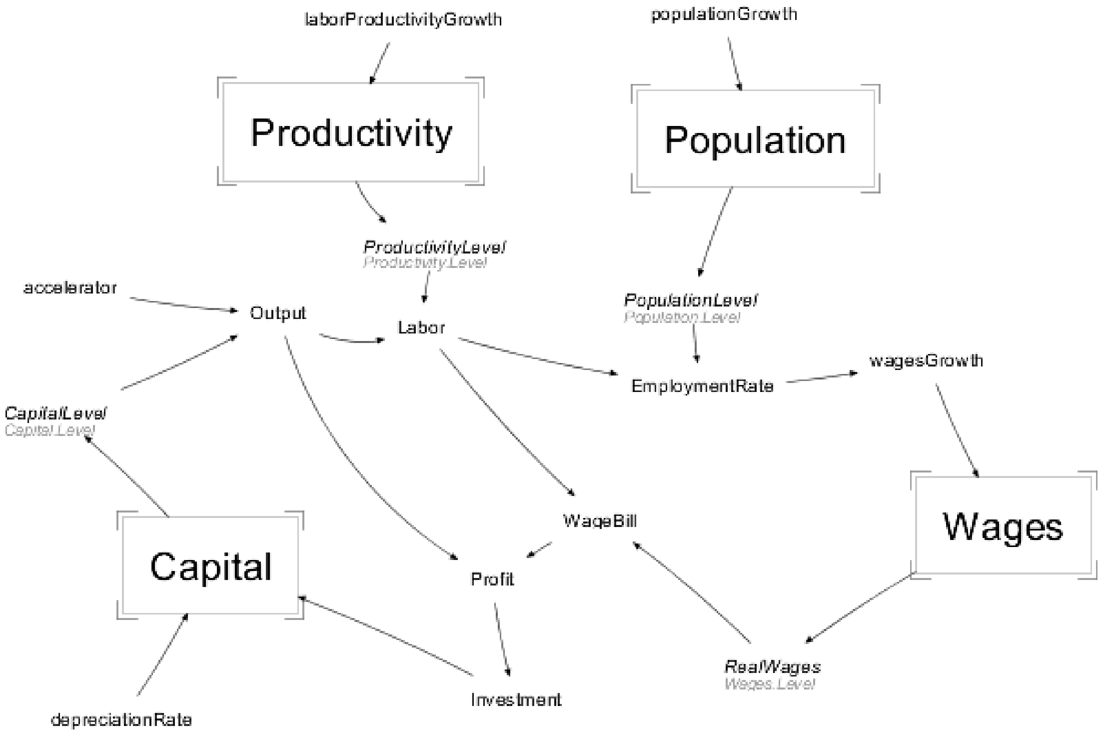

Figure 7. The system dynamics diagram of basic linear Goodwin's cycle

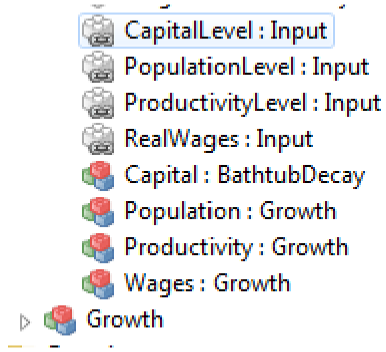

Figure 8. The sub component that produce Goodwin's cycle module

For the real wage, labor productivity and population growth differential equation, the building block is just using exponential growth patterns. Using the module as shown in the figure below, the input is growthRate, the output is Level, and the parameter is initialLevel.

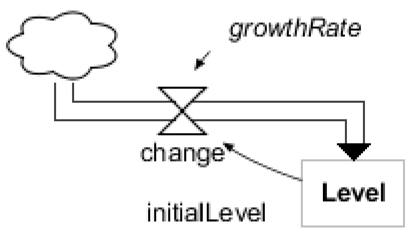

Figure 9. A module for real wage, labor productivity and population growth

Component of capital stock is made from two patterns; Bathtub and Decay. The inputs are rateOfIncrease and rateOfDecrease which are connected to Investment and depreciationRate, the output is Level, and the parameter is initialLevel. The building block of the module is shown in diagram below:

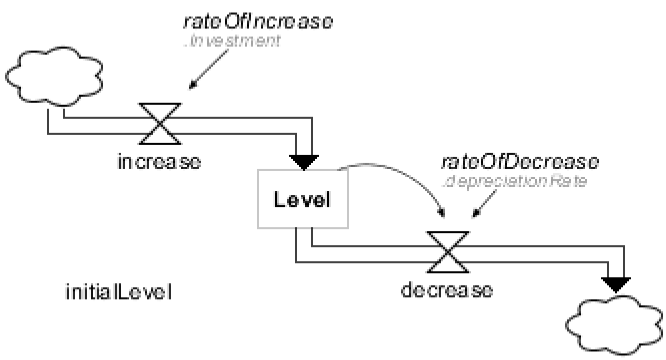

Figure 10. A module for capital stock

The resulting behavior using initial value of (0.95, 900, 1, and 300) for the real wage, capital stock, labor productivity, and population growth is shown in the figure below:

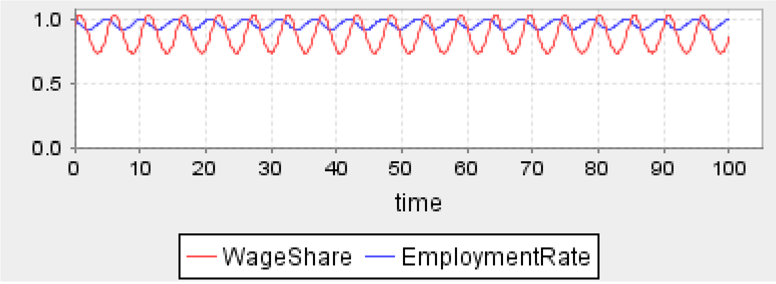

Figure 11. The cycle between WageShare and EmploymentRate

The Output keeps rising because of the other exponential components with positive growth rates. The Output is also modulated in a cycle of 6-8 years in this model as shown in the figure below.

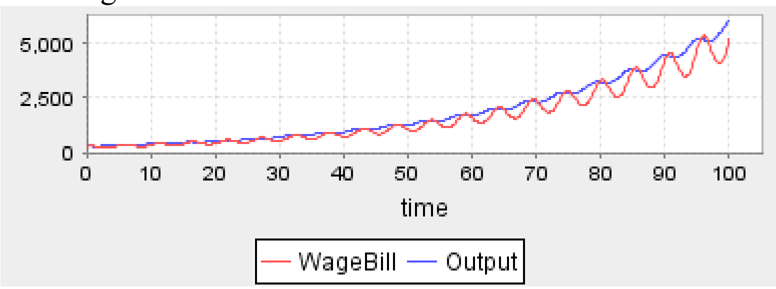

Figure 12. The pattern of Output growth in basic Goodwin's cycle

The alternative version of the cycle can also be made from feedback loop between EmploymentRate and Wages as shown in the figure below:

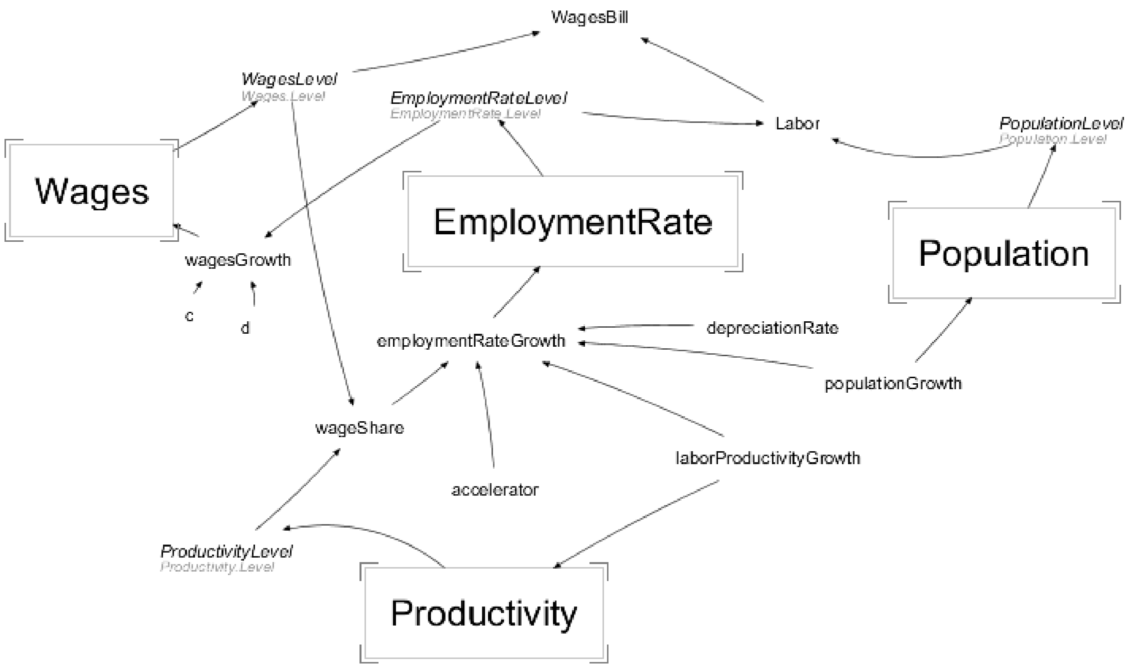

Figure 13. Another variation of Goodwin model

The descriptions of the four building blocks are:

1. Population N is determined by population growth β: $\frac{dN}{dt} = \beta \cdot N$
2. Labor productivity a is determined by labor productivity growth α : $\frac{da}{dt} = \alpha \cdot a$
3. Rate of change of employment rate $\frac{d\lambda}{dt} = \left(\frac{1-\frac{w}{a}}{v}\right) - \gamma - \alpha$
4. Rate of change of real wages $\frac{dw}{dt}$ is determined by the wage rate w and employment rate λ via a linear Phillips curve : $\frac{dw}{dt} = (-c + d \cdot \lambda) \cdot w$ where c and $d$are coefficient of linear Phillips curve

From the above four differential equations we can now calculate:

1. Labor L is employment rate λ times population N : $\lambda = \frac{L}{N}$
2. Wage bill W is wage rate w times employment L : $W = w \cdot L$
3. Level of output Y depends on level of employment L and labor productivity a : $Y = L \cdot a$ (not shown in the diagram)
4. Level of capital stock K is determined by level of output per annum Y and accelerator v : $K = Y \cdot v$ (not shown in the diagram)
5. Rate of change of capital stock $\frac{dK}{dt}$ equals to Investment I minus depreciation $\gamma \cdot K$: $\frac{dK}{dt} = I - \gamma \cdot K$ (not shown in the diagram, and just become an auxiliary variable not a stock-flow pair)

Using initial value of (0.95, 1, 1, and 300) for the real wage, employment rate, labor productivity, and population growth, the result is

Figure 14. The behavior is the same with the previous model

The combination of the two building blocks can be seen in (Utama, 2013)

STOCK FLOW CONSISTENT: SIMPLEST MODEL WITH GOVERNMENT MONEY

The content of this section mainly extracted from (Godley & Lavoie, 2007) and (G. Renfro, 2009) unless stated otherwise.

Let us start with the simplest meaningful model that can be built – Model SIM, for simplest. The economy is closed to the outside world: there are neither exports nor imports, nor foreign capital flows. We postulate a monetary economy in which economic agents, beyond the institution of government, can be divided conceptually into their business activities on the one hand, selling services and paying out wages and, on the other, receiving income, consuming and accumulating assets when they act as households. All production is under taken by providers of services, who have no capital equipment and no intermediate costs of production. Production of services is assumed to be instantaneous, so that inventories do not exist. Finance for inventory accumulation is thus unnecessary. There are no private banks, no firms and no profits whatsoever. We are in a pure labor economy, àla Adam Smith, where production is carried out by labor alone. And the government finances deficits by issuing currency only which means the abstraction of a pure fiat money economy.

In a closed, simplified economic system, total production (also commonly identified as Gross Domestic Product in a more generalized setting) can be defined as either the sum of all paid expenditures on newly produced goods and services or as the sum of all payments of factor income:

$Y = C + G = W$

Where

C = Consumer Expenditures

G = Government Expenditures

W = the sum of factor incomes (which here, by assumption, has been simplified to the wage bill)

It is important to recognize the system-defining significance of such accounting identities.

Often, in economic textbooks and other such contexts of economic discourse, the focus is placed almost entirely upon the behavioral characteristics of economic agents. However, when modeling macroeconomic behavior, it is important to recognize that the accounting identities themselves provide an important structural element and fundamentally affect how the model behaves and reflect structural economic characteristics.

As well as the simplified total production (GDP) identity displayed above, the model SIM also includes among its identities the concept known as disposable income (YD):

$$YD = w * N - T$$

the government budget constraint:

$$Hg - Hg(-1) = G - T$$

and the household budget constraint:

$$Hh - Hh(-1) = YD - C$$

As they stand, they are each simplifications and this simplification is perhaps most evident in the wage identify, which defines the (average) wage as total income divided by the number of people employed. For one thing, it needs to be recognized that this wage variable is a weighted average and, in a more realistic context, is therefore partially dependent upon the distribution of income for its value.

The two most obviously behavioral equations in the model are the consumption function:

$$C = alpha1* YD + alpha2 * Hh(-1)$$

and the tax yield equation:

$$T = theta * w * N$$

each of which include behavioral or policy parameters (namely, alpha1, alpha2, and theta).

The first two of these are behavioral in the sense of stating what percent of the disposable income and what fraction of household cash holdings are (by assumption) characteristically expended on consumer expenditure. Theta is policy determined in the sense of being an (ex post) policy-determined variable that specifies what proportion of total income is taxed by the government.

The model also “includes” the redundant equation

$$Hh – Hh(-1) = Hg – Hg(-1)$$

which is automatically satisfied by any solution of the model. However this equation is not explicitly included because its explicit presence would over-determine the model. And it provides a way to consistently checking the result of simulation by representing it as a "sectoral" balances equation

An additional behavioral equation is the employment equation

$$N = Y/w$$

which can be seen to originate in a renormalization of the Wage Identity, so as to state, in effect, the behavioral characteristic that the relationship between production and wages determines employment.

The stock flow consistent model usually written in the form of recurrence relation which looks like lagged or AR (auto regressive) equations, which should be converted first to difference equations. The existing software tools for solving the stock flow consistent equations are:

1. Excel spread sheet by Javier López Bernardo (http://models.sfc-models.net/gl2007/excel.php)
2. Eviews program by Gennaro Zezza(http://gennaro.zezza.it/software/eviews/gl2006.php)
3. R package: SFCPackage (Gauss-Siedel) (http://www.antoinegodin.eu/sfc)
4. Matlab code (Gauss-Siedel) (Kinsella, 2010)
5. Modler code (Gaus-Siedel) (G. Renfro, 2009)

First we have to convert it into first difference equations. We have two stocks (Hh and Hg) with their initial values set to zero and two exogenous variable.

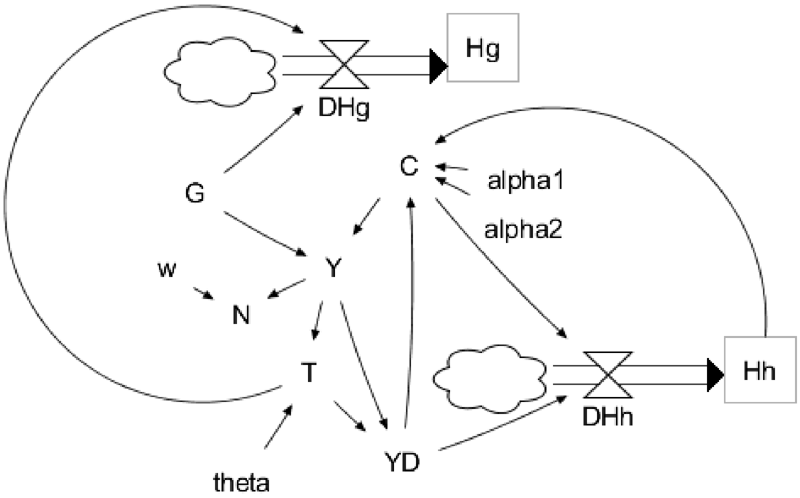

Figure 15. The original difference equation converted into system dynamics diagram

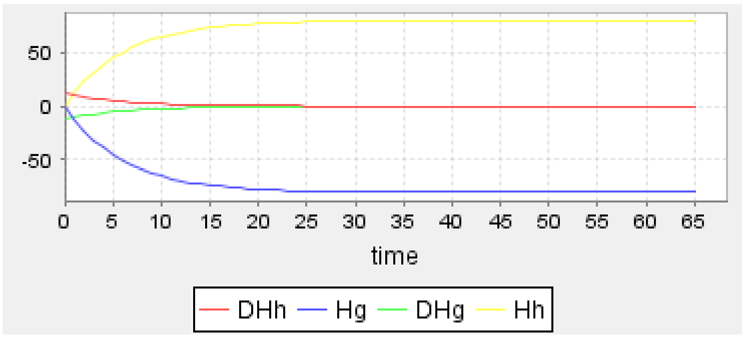

Figure 16. Sectoral Balance

Then, we rename all variables into concise and meaningful variables

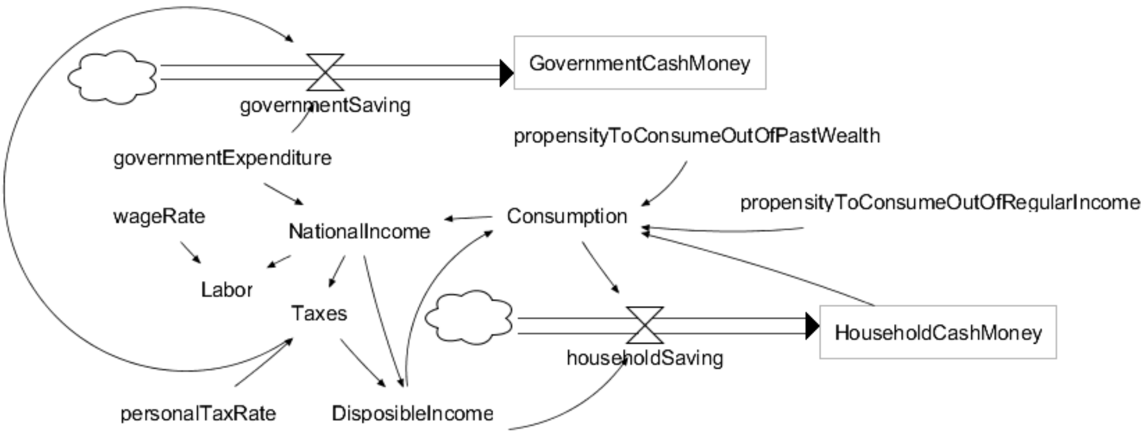

Figure 17. Result of renaming all variables, not component based

Usually, most of the system dynamics models stop in this step. But if we want to add another sector such as Banks for saving and loan, Central Bank for money supply, or even adding the Rest of The Worlds for import and export. We might also want to put the model in the larger framework such as Aggregate Demand – Aggregate Supply (AS-AD) framework. Then we will quickly loss of sight for the big picture, because of complexity of connection and feedback. Even if making a block there is no clear boundary or demarcations and no explicit connection, usually using shadow variable.

First attempt of refactoring

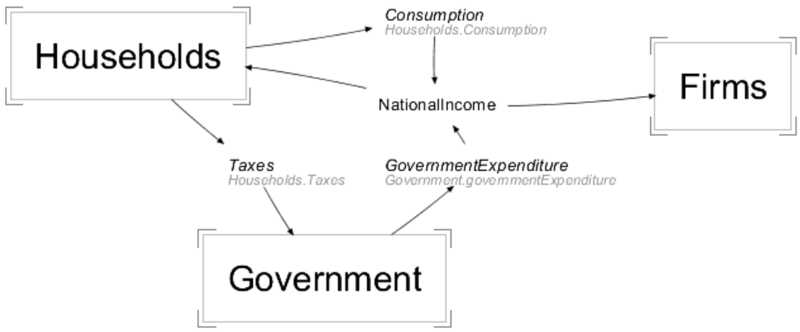

Figure 18. Initial block of sectoral divisions and their connection based on the equations alone

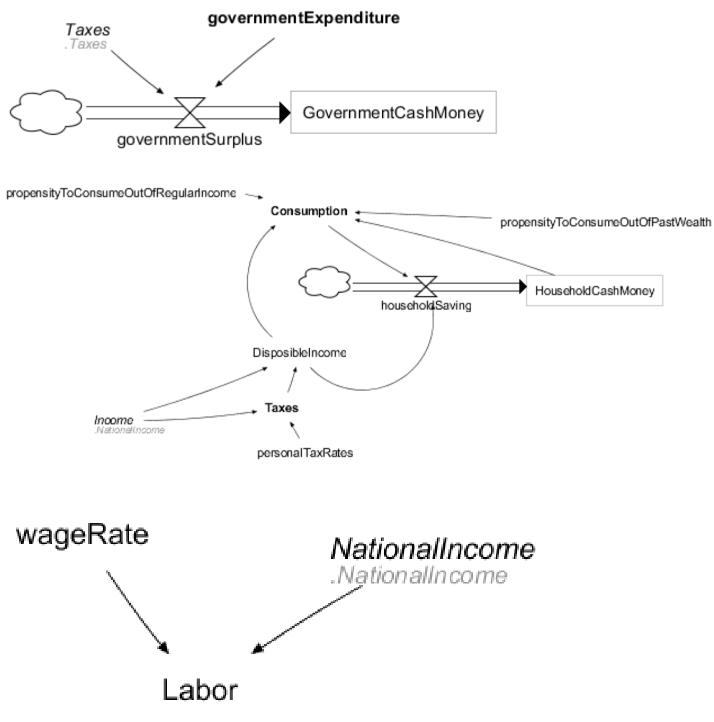

Figure 19. Government, Household, and Firm Module

From the perspective of entity at least every entity should have at least one account: cash or current account and the system dynamics representations will quickly recognize this function. However in this step, the firm module has no stock at all, because the national income (GDP) is equal to wage. So there is no change in the firm account.

Second attempt of refactoring

We should take a baby step to refactor the model by change it a little bit and check their sectoral balance. Even though the equation has not changed, but the model readability and understandability increase greatly. Now, if we take a look at the transactions matrix, actually it is much clearer if we just follow the table.

Flow/Stock	**Households**	**Firms**	**Government**	∑
Govt. expenditure		+G	-G	0
Consumption	-C	+C		0
[GDP(memo)		[NationalIncome]		
Wages	+W	-W		0
Taxes	-T		+T	0
Change of Stock = ∑	SAVING	0	SURPLUS	0

Figure 20. Transaction Table, also representing identity equations

The explanation of the flow and its substitution is described in the table below

Flow	**Expression**	**Parameter values for simulation**
Consumption	$C = \alpha_1 YD + \alpha_2 H_h(-1)$	$H_h(0) = H_g(0) = 0$ $\theta = 0.2$ $w = 1$ $G = 20$ $\alpha_1 = 0.6$ $\alpha_2 = 0.4$
Tax	$T = \theta * w * N$	
Employment	$N = Y/w$	

Figure 21. Table of behavioral equations and parameters for the SIM model

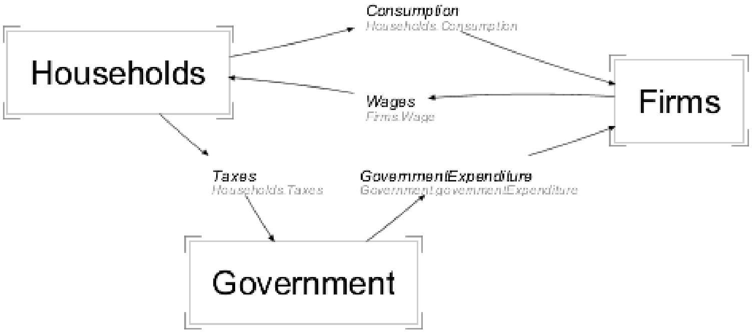

Figure 22. Government, Household, and Firm Module

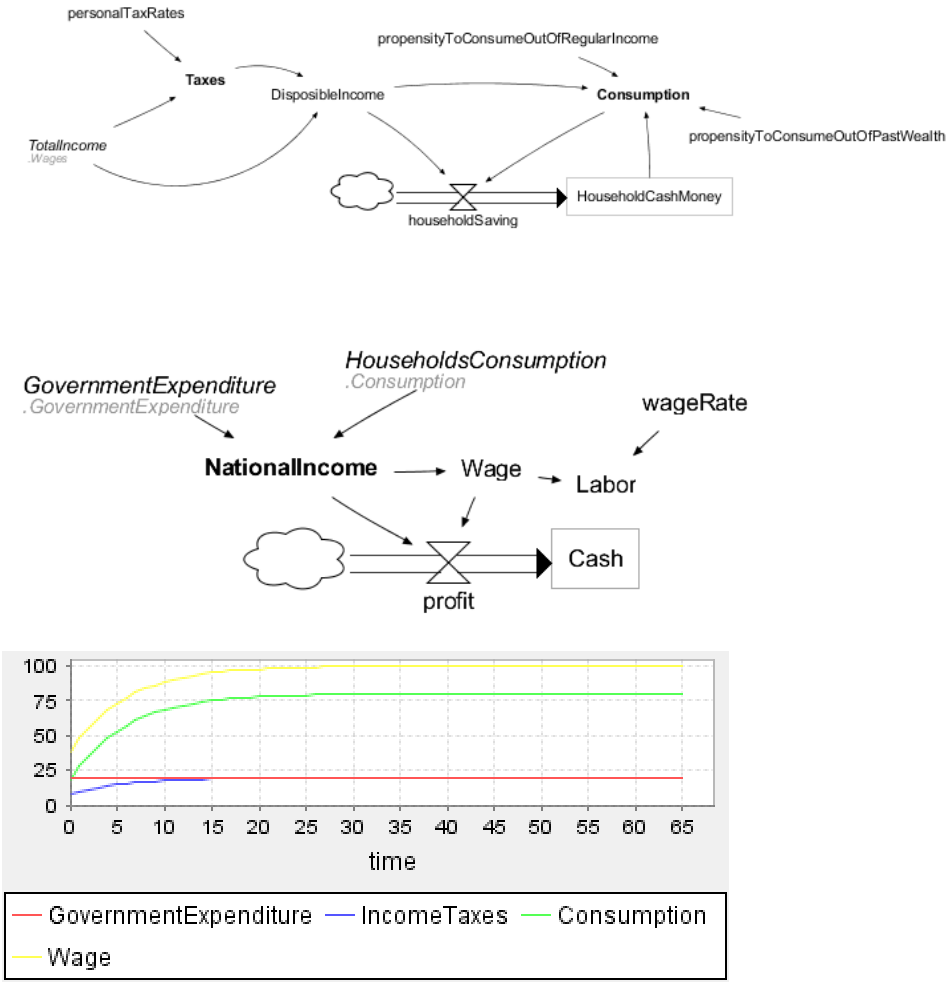

Figure 23. Household, Firm Module and the flow between sectors

Adding more transaction

Firms have two kinds of financial decisions, for financing and investments. For the simplest case, let assume the firms self-financing, with the firm profit determined by wage share and all profit put into the investment

Flow/Stock	Households	Firms		Government	∑
		Current	Capital		
Govt. expenditure		+G		-G	0
Consumption	-C	+C			0
Investment		+I	-I		0
[GDP(memo)		[NationalIncome]			
Profit		-P	+P		0
Wages	+W	-W			0
Taxes	-T			+T	0
Change of Stock = ∑	SAVING	0	0	SURPLUS	0

Figure 24. Adding Firm Profit and Investment to transaction matrix

We only have to modify the Firm module by separating the Firms into two accounts, current and capital account. As we can see the last row define what we called sectoral balance, which also worked if we add another sectors such as Banks, Central Bank the Rest of the Worlds, like Godley said himself: "it came as a shock to discover that if only one knows what the budget deficit and private net saving are, it follows from that information alone, without any qualification whatever, exactly what the balance of payments must be" (Godley & Lavoie, 2007).

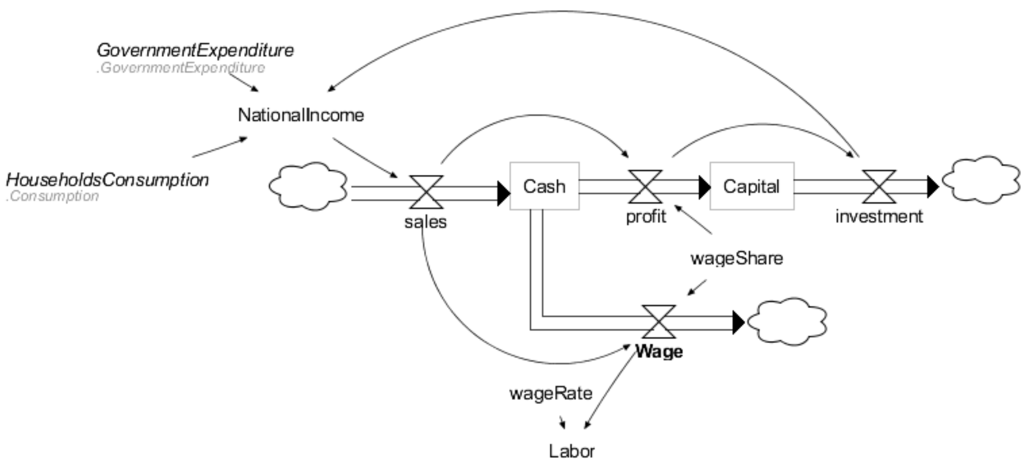

Figure 25. The Firm module after adding profit and investment

Chapter 4. Conclusions

CONCLUSIONS

The fact that money stocks and flows must satisfy accounting identities in individual budgets and in an economy as a whole provides a fundamental law of macroeconomics analogous to the principle of conservation of energy in physics. (Godley and Cripps, 1983).

We have shown how to use system dynamics to solve simultaneous equations whether the equations are static (no time index difference) or dynamic (using difference and differential equations). Concerning the way SD deals with time we can say that SD is a kind of “hybrid” methodology, being compatible with both the continuous and the discrete concept of time (Ossimitz G., 2008). We also shown how to reuse and refactor existing sample of stock flow model into a component based system dynamics model. We decompose the module based on sectors with explicit transfers between sectors. The transaction between the sectors is represented by granular transactions.

In other disciplines like physics, technical or engineering it is relative easy to find standard component for modeling. For example: resistor, capacitor, and inductor in electric or linkage, motor, turbine, and process tank in other engineering fields. In contrast to this, the social sciences especially finance and economics which are quantitatively based, it is very hard to find this kind of component model. The physical components are acausative type model utilizing concept of effort and flow variables. The benefits of component based modeling are abundant. It can decrease the modeling cost and time by using standard component. It is also relaxing the requirement skill for beginner in modeling.

We hope the methodology presented here will inspire communities from econometrics and stock flow consistent to use system dynamics and vice versa. There are a lot of stock flow consistent model and structural equations model out there waiting to be casted and digested into system dynamics form. And by realizing that we can also use convert existing system dynamics model into difference equation and then into structural equation models, the SD communities can use the available econometric tools and data for doing estimation and extrapolation based on aggregate statistics generated by the economy and collected through the national account. System Dynamics can become a bridge between these communities by providing a common language for them.

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