MONETARY ECONOMICS: POST-KEYNESIAN STOCK-FLOW CONSISTENT APPROACH (PK-SCF) VERSUS NEW-KEYNESIAN DYNAMIC STOCHASTIC GENERAL EQUILIBRIUM (NK-DSGE)

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Abstract

In this paper we are thinking like Keynesians. In the first part we are modeling economy by using Post-Keynesian Stock-Flow consistent model (PK-SCF), later we employ New- Keynesian Dynamic Stochastic General Equilibrium model (NK-DSGE). Keynesian SFC practitioners strongly believe that their models are closer than others to the ideal of providing macroeconomists with logical equivalents to 'artificial economies'. DSGE practitioners on the other hand think that there is no credible alternative in macroeconomic policy thinking to theirs. Authors personally think NK-DSGE model to be superior since it is micro founded and it is improvable.

Keywords: PK-SCF, NK-DSGE, monetary economics

JEL: E12, E50

Introduction

In this paper we will review two views: Post-Keynesian and New-Keynesian through the lens of their state-of-the-art models, Stock-Flow consistent model of macroeconomics modeling (SCF) and Dynamic Stochastic General Equilibrium model (DSGE). Post-Keynesian economics is often associated with the fundamentalist readings of the John Maynard Keynes's *The General Theory of Employment, Interest and Money* (1936), but also is associated with the Polish economist Mikhal Kalecki who is said to have discovered Keynes principles of effective demand on his own. Kalecki formulation of the principles of effective demands in a 1934 paper entitled *Three systems* did not specify the state of the competition though it assumed increasing marginal costs and that price equals to marginal cost. Kalecki brought up in the Marxian tradition attempted to provide theoretical explanation on why "growth under capitalism is characterized by the recurrence of cycles", see Lopez (2002).Kalecki dismissed explanation of Keynes that the wage fall will bring full employment, in his alternative realization the wage fall will depress demand. In Kalecki's business cycle model, investment (with output and employment) does not converge towards full level of employment but does fluctuates cyclically. Sawyer (2001), asserted that Kalecki did not see imperfect competition as a cause of unemployment in the early period[1]. In the latter period Kalecki analysis included the term "degree of monopoly power". Though the first wave New- Keynesian economics did not included "imperfect competition" in the analysis with the papers mainly concerned with sticky prices and staggered wage setting (see e.g. Fischer (1977); Taylor (1979;1980), Akerlof ,Miyazaki (1980)).In 1980's the concept of menu costs and monopolistic competition as a concepts were used to explain price stickiness. The idea of nominal price rigidity (wage stickiness) was put forward by the economists Akerlof, Yellen (1985, a,b),and later Blanchard, Kiyotaki (1987), their rationale was that not adjusting prices for firms and unions was of second order loss but it's a first-order loss for the economy as a whole. Mankiw

[1] As Sawyer (2001) point out Kalecki among other things did write about (in two Volumes VI and VII): in Volume VI themes from applied economics, Cartels and trusts (cartels come from pursuit of power rather than efficiency reasons) , Nazi Germany (interplay between economic force and political forces), indices of business fluctuations, national income accounts, prices costs and a cycles. In the Vol. VII Kalecki writes about rationing (he prefers rationing over taxation), Inflation ("inflation is sometimes defined as a state in which rising (effective) money demand for goods not met by similar increase in supply"),share of wages and profit, but he ignored monetary factors unlike Keynes (though Kalecki saw that the expansion of economic activity required creation of credit, and second the idea that the amount of money into existence depends on the demand for money,any excess money are extinguished by the repayment of loans) , burden of national debt,the welfare state and employment, and international arrangement, In conclusion Kalecki had been versatile economist.

(1985) also considered the welfare effects of changes in output as a result of sticky prices. Taylor (1979)-Calvo (1983) foundations, asserted that money growth (change) has a maximum effect on activity after one year, and that effect is gone in 3 years. Taylor-Calvo equations are capturing staggering and price decisions and are the basis modeling nominal rigidity in New Keynesian DSGE models. So this paper has a task to provide review of the parameters and solutions for the main arsenal of Post-Keynesian economics namely (SFC-stock flow consistent mode) and New-Keynesian DSGE (Dynamic Stochastic General Equilibrium model) model that origins from RBC model and one such model will be set up and we will continue with RBC with New-Keynesian features basically NK-DSGE model with sluggish prices(forward) and Inflation smoothing (backward).PK-SCF models will be presented with : Simple model with government money; Long term bonds capital gains liquidity preferences ; and the model with inside and outside money.

2. Literature survey: Post-Keynesian SCF

Stock-flow consistent (SCF) approach was developed in the early and mid-2000's by Godley and Lavoie (2007a) and Godley and Lavoie (2007b). As Godley and Lavoie (2007a) point out that at the Levy Economics Institute in the state of New York there was revival of interest in stock-flow consistent approach to macroeconomic modelling, or as it is named sectoral money-stock consistent flow approach. This revival of interest was exemplified and visible in the works of : Godley (1996, 1997, 1999a,b) and Godley and Shaikh (2002), but also those of Dos Santos (2002a,b, 2005, 2006), Izurieta (2003), Lavoie and Godley (2001–2), Lavoie (2003), Moudud (2007), Taylor (2004a,b), Foley and Taylor (2004), Zezza ; Dos Santos (2004), who all explicitly refer to a social accounting matrix (SAM)[2] approach or to stock-flow consistency (SFC).As it is asserted in Godley ;Lavoie (2007a), part of this revival can be attributed to: Flaschel, Franke ,Semmler (1997); Chiarella ,Flaschel (2000); Flaschel, Gong ;Semmler (2001) also. This part of the review can be completed with these works: as Lequain (2003), Kim (2006a,b), Mouakil (2005), Le Héron (2006), Tymoigne (2006), Clévenot and Mazier (2005), Firmin (2006), Zhao (2006) ;Charpe (2006).Two schools can be identified to have developed models based on stock-flow consistent (SCF) approach to macroeconomic modeling. First school was located at Yale university and was led by Nobel prize winning economist James Tobin[3], the other one was the department of Applied economics at Cambridge university, and this school was led by Wynne Godley. Another post-keynesian author that is concerned with the SCF approach in Eichner (1987), who presents the endogeneity of money, the creation of loans, as well as CB operations through a balance-sheet approach, where distinction has been made between the financial sector and two non-financial sectors. This approach is explicitly tied by Eichner (1987) to the paper by Godley ;Cripps (1983).These two groups of economist it is known to have work independently until conference in honor of Keynes in 1983 had taken place at Cambridge university. The Yale group or so called "pitfalls approach" focused its attention to portfolio and asset choice, its inspiration has been neo-classical general equilibrium theory. The Cambridge group which is also known as Cambridge Economic Policy Group (CEPG), or the New Cambridge school, used the SCF framework mainly for forecasting whether expansion was sustainable, and also to discuss BP problems that were plaguing GB in 1980's see Godley (1999c).Godley, Lavoie (2007a) have cited the work of Tobin especially Backus, Brainard, Smith and Tobin (1980) as an example of the most empirically oriented approach in the stock-flow approach to macroeconomic modeling. In his Nobel prize speech (1981) published in Tobin (1982a), he distinguished four main characteristics of his work that do apply also to SCF approach, namely:

[2] Social accounting matrix (SAM) represents flows of all economic transactions that take place within an economy (regional or national).It represents a matrix representation of national accounts (national accounting or social accounting),but it can be extended to include non-national accounting flows. These Social accounting matrices (SAMs) are providing a static picture of the economy and are referring to one year only. This approach employs social accounting matrices to ensure that every flow of payments comes from somewhere and goes somewhere and that every financial stocks is recorded as a liability for someone and an asset for someone, so that there are no financial black holes in the model

[3] See Brainard and Tobin (1968) on the portfolio approach ,Tobin,De Macedo (1980) "which presented the most explicit and most empirically-oriented version of the research programme that was being pursued at Yale University on the stock-flow consistent approach to macroeconomic modelling"..Godley;Lavie (2007a) ;Tobin(1982a;b)

precision regarding time and tracking of stocks[4], several assets and rates of return[5], modeling financial and monetary operations, and on this topic about monetary operations Tobin (1982 a) further explained:.." "money supplies are changed by government transactions with the public in which goods or nonmonetary financial assets are exchanged for money, or by similar transactions between banks and the nonbank public" and Walras's Law and adding-up constraints[6].In the stock-flow consistent approach (SCF), contrary to neo-classical economics, the adjustment process towards the steady-state is based on the simple reaction functions to disequilibria. Post-Keynesians are not assuming that firms maximize profits or that economics agents' individuals are maximizing utility, also the presumption of perfect information is irrelevant in the SCF model. During 1970's and 1980's see Godley, Cripps (1983) inspired by Minsky, Kalecki, Tobin developed their "flow of funds" approach to macroeconomics that aimed at providing comprehensive integrated representation of the economy, including all financial transactions and changes in money supply, see Caiani et al.(2016). Using flow of funds accounts to analyze the US economy at the end of 20th century, Godley and Wray (1999) and Godley and Zezza (2006) implied that growing households' indebtedness was pushing assets' inflation and leavening systemic risk under the surface of the alleged stability of the early '00s, thereby anticipating the crisis with significant precision regarding the timing and mechanics of the collapse .In 2011 CB of England had used flow of funds approach to analyze the mechanics of financial instability. In support of this Barwell and Burrows (2011) advocated the diffusion of macroeconomic approaches that stress the importance of balance sheet linkages when spotting the points of buildup of financial instability.The roots of PC-SCF (Post-Keynesian Stock-Flow consistent approach to macro modeling) can be traced back Morris A. Copeland (1949), who, with his study on 'money flows', is the father of the flow of funds (For FED Z.1 release), see Caverzasi, Godin (2014). Agents in the SCF models are displaying according to Godley (2007a) *procedural rationality, or bounded rationality*, even more so *reasonable rationality*. Psychologist have claimed that individuals are taking their decisions on the basis of satisficing[7].This concept was introduced by Simon (1956), though the term as such was introduced much earlier in Simon (1946). Psychologist say that people make decisions based on frugal heuristics, and that this decisions are better or same as the ones that would be based on compensatory criteria or linear regressions, see Gigerenzer; Todd (1999).About the e empirics of these models only two groups of authors have been working on fully empirical models: Godley, Zezza and other authors related to the Levy Institute (see, e.g., Godley ;Zezza, 1989; Zezza, 2009, 2011; Papadimitriou et al., 2011); and Kinsella and Tiou-Tagba Aliti, 2012. It is also worth mentioning the work of Clévenot et al. (2009, 2010), who estimate the parameters basing their econometric analysis on their own model. Dynamic SFC modeling has its limitations and critics see Caverzasi, Godin (2014). Keynesian critique to the early econometric models, see Keynes (1939) might apply also to SCF models. Since, there is no guarantee that macroeconomic parameters such as for instance, coefficients describing the consumption function, will remain constant during the simulation period. Lucas critique (see Lucas (1976)), because these models lack micro foundations in neoclassical sense. Basic idea of Lucas critique is that estimated parameter derived from econometric studies that are describing aggregate behavior of agents may

[4] Tobin (1982a) here explained "A model of short-run determination of macroeconomic activity necessarily refers to a slice of time. It is one step of a dynamic sequence, not a repetitive equilibrium into which the economy settles" …." An essential part of the process is the dynamics of flows and stocks, investment and capital, saving and wealth, specific forms of saving and asset stocks. It is not generally defensible to ignore these relations on the excuse that the analysis refers to so short a time that stocks cannot change significantly

[5] .."My alternative framework can in principle accommodate as many distinct asset categories as appropriate for the purpose at hand, though the illustrative application set forth below distinguishes only four. Asset disaggregation is essential for analyzing, among other phenomena, financing of capital accumulation and government deficits, details of monetary and debt management policies, international capital movements and foreign exchange markets, and financial intermediation"..

[6] .." For the asset markets modeled below, for example, the implication is that household demands for end-of-period holdings of the several assets sum to household demand for end-ofperiod wealth, for every set of values of the determinants of asset and wealth demands.This implies that the partial derivatives of asset demands with respect to, say, any interest rate must add up to the partial derivative of wealth demand with respect to the same variable"…" As my collaborator William Brainard and I observed (Brainard, Tobin(1968) , this consistency requirement is not always explicitly observed in theoretical and statistical models of financial markets

[7] According to Manktelow, (2000), satisficing is a decision-making strategy or cognitive heuristics, that involves searching the alternatives until some threshold that is acceptable is met. The term satisficing is a portmanteau of satisfy and suffice.

change if policy changes, if these parameters are not structural i.e. grounded in the rules governing the behavior of individual agents. Next, due to presence of stochastic disturbances i.e. risk and uncertainty the forecasting accuracy of these models diminishes across time. These models cannot stimulate shifts in investor or consumer confidence and agents associated with speculative bubbles.

2.1 Literature survey: New-Keynesian DSGE

People often use term DSGE to refer to the quantitative models of growth or business cycle fluctuations. A classic example of DSGE model is the Real Business Cycle (RBC) model associated with Kydland; Prescott (1982) and Long and Plosser (1983). These early RBC models assumed economy populated by households who participate in perfectly competitive, goods, factor and asset markets, see Christiano et.al. (2018). These models took the notion that aggregate fluctuations in the economy are an efficient response of the economy to the source of uncertainty, and the exogenous technological shocks[8]. New Keynesian DSGE models have been built on the basis of these RBC models to allow nominal frictions, in labor and goods markets. The DSGE model proposed by Christiano, Eichenbaum, and Evans (2005) and later estimated by Smets and Wouters (2003) using Bayesian techniques, is currently considered to be a benchmark richly specified DSGE model for a closed economy, see Kolasa et al. (2012).These models may be called Friedmanite DSGE models, since they assume that monetary policy has no effect on real variables such as: output and real interest rate in the long run. But due to sticky prices and wages, monetary policy matters in the short run. Thus, these models do embody fundamental view of the Friedman (1968), seminal Presidential Address to the American Economic Association. So, a transitory fall in nominal interest rate (policy induced) is associated with a decline in real interest rate, an expansion of economic activity and a small to moderate rise in inflation. New- Keynesian DSGE models such as Yun (1996), Clarida, Galí, and Gertler (1999), and Woodford (2003), it is said to satisfy Fisherian and anti-Fisherian property. Fisherian property satisfies that *permanent* changes in monetary policy induce roughly on-to-one changes in inflation and nominal interest rate (neutrality of money); and anti-fisherian property states that *transitory* changes in monetary policy induce movements in nominal interest rates and inflation of the opposite sign. DSGE models have been subject to negative scrutiny recently by New-Keynesian or Neo-Keynesian economists such as Blanchard (2018) and Stiglitz (2018). For instance, Blanchard (2018) takes negative stance on the assumption on which these models are built. Namely, aggregate demand is derived as consumption demand for infinitely long lived and foresighted consumers. He continues to argue that its implications for the degree of foresight (through the value of discount factor) and the role of interest rate. Price adjustment is characterized by a forward-looking inflation, which does not capture the fundamental inertia if inflation. The equation characterizing the behavior of consumers is known as the 'Euler equation'. The equation characterizing the behavior of prices is derived from a formalization offered by Guillermo Calvo and is thus known as "Calvo pricing". As per Blanchard (2018), the standard method of estimation of these models is a mix of calibration and Bayesian estimation and is unconvincing. Since the three equations are estimated as a system, rather than equation by equation and they come with many parameters to estimate, so that the estimation is unfeasible[9]. Problems could arise from misspecification in one part of the model which will affect estimation of the parameters in other part of the model. Next, normative implications on the micro founded models are not convincing…" To take a concrete example, the adverse effects of inflation on welfare in these models depend mostly on their effects on the distribution of relative prices, as not all firms adjust nominal prices at the same time. Research on the benefits and costs of inflation

[8] According to Christiano et al.(2018) RBC models crumbled because of the three assumptions: micro data that cast doubt on the key assumptions of the mode such as: perfect credit and insurance market, frictionless labor market ("in which fluctuations in hours worked reflect movements along a given labor supply curve or optimal movements of agents in and out of the labor force"…);second these models did not take into account volatility in hours worked, the equity premium (the difference between the return on a stock and the return on a bond); the low co-movement of real wages and hours worked see Christiano and Eichenbaum (1992); King and Rebelo (1999).Third because these models did not take money into account those models seemed to be inconsistent with the economists explanations of various historical episodes such as for instance US recession in 1980's which was predominately provoked by monetary factors.

[9] "..For example, in the face of substantial differences in the behaviour of inflation across countries, use of the same 'standard Calvo parameters' (the parameters determining the effect of unemployment on inflation) in different countries is highly suspicious. In many cases, the choice to rely on a 'standard set of parameters' is simply a way of shifting blame for the choice of parameters to previous researchers",Blanchard (2018)

suggests, however, a much wider array of effects of inflation on activity and in turn on welfare", Blanchard (2018).Furthermore Blanchard criticizes the complexity of these models as he points out:" for the more casual reader, it is often extremely hard to understand what a particular distortion does on its own and then how it interacts with other distortions in the model". Blanchard (2017) suggests: "The models should capture what we believe are the macro-essential characteristics of the behavior of firms and people, and not try to capture all relevant dynamics. Only then can they serve their purpose, remain simple enough, and provide a platform for theoretical discussions". Stiglitz (2018) cites Korinek (2017) in what is referred to as "devastating critique": Times series are HP filter detrended "to focus the analysis on stationary fluctuations at business cycle frequencies"[10]. Christiano et.al. (2018), elaborates that previous is simply incorrect, and that DSGE literature adopts different strategies for dealing non-stationarity data, see Comin and Gertler (2006). Stiglitz (2018) than continues "for given detrended time series, the set of moments chosen to evaluate the model and compare it to the data is largely arbitrary—there is no strong scientific basis for one particular set of moments over another … For a given set of moments, there is no well-defined statistic to measure the goodness of fit of a DSGE model or to establish what constitutes an improvement in such a framework.".Christiano et al.(2018) reply to this critique:" this criticism might have been appropriate in the 1980s. But it simply does not apply to modern analyses, which use full information maximum likelihood or generalized method of moments". Next Stiglitz (2017) critique is that pre-crisis DSGE models did not allow for financial frictions and liquidity constrained consumers, though than existing literature denies this as Galí, López-Salido, and Vallés (2007) investigate the implications of the assumption that some consumers are liquidity constrained. They find that liquidity constraints magnify the effects of government spending. Previously, Carlstrom and Fuerst (1997) and Bernanke, Gertler, and Gilchrist (1999) develop DSGE models that incorporate credit market frictions.

3.PK-SCF simple model with government money

Government money is usually called central bank money or high-powered money[11].The identity of high-powered money is as.

equation 1

$$H = C + RR + ER$$

Where H-stands for high-powered money, C-is currency, RR −is equal to required reserves; and ER-represents excess reserves. The money supply$M$ consists of deposits held by commercial banks D; and currenct C held by public:$M = D + C$.From previous we know that $H = C + RR + ER$; so if we divide previous two equations:

equation 2

$$\frac{M}{H} = \frac{D + C}{C + RR + ER}$$

If we divide numerator and denominator in previous equation by D we get "

equation 3

$$\frac{M}{H} = \frac{1 + \frac{C}{D}}{\frac{C}{D} + \frac{RR}{D} + \frac{ER}{D}} = \frac{1 + C_\gamma}{C_\gamma + RR_\gamma + ER_\gamma} \Rightarrow H = \frac{C_\gamma + RR_\gamma + ER_\gamma}{1 + C_\gamma} \times M$$

[10] HP filter will be optimal when: data exist in I(2) trend, noise data are normally distributed (approx.); analysis must be historical and static, since the filter causes misleading predictions when used dynamically, see French (2001).

[11] High-powered money is the sum of commercial bank reserves and currency (notes and coins) held by the Public. High-powered money is the base for the expansion of Bank deposits and creation of money supply

In previous $\frac{C}{D} = C_\gamma$ is the currency ratio; $\frac{RR}{D} = RR_\gamma$ is the reserve ratio and $\frac{ER}{D} = ER_\gamma$ is the excess reserve ratio. And from previous equation we have that :

equation 4

$$M = \frac{1 + C_\gamma}{C_\gamma + RR_\gamma + ER_\gamma} \times H \Rightarrow M = m \times H$$

Where m is the money multiplier. This equation tells us how much money will be created by the banking system for a given rise in the high-powered money. The equations in this model are:

Table 1 Equations for the simple model with government money

Equation	**Explanation**
1. $C_s = C_d$ 2. $G_s = G_d$ 3. $T_s = T_d$ 4. $N_s = N_d$	$C_s; C_d$ are the consumption goods supplied by the firms and demanded by the household. $T_s; T_d$ are the taxes supplied and demanded by the government, $N_s; N_d$ are the supply and the demand for labor.
5. $YD = W \cdot Ns - Ts$ 6. $T_d = \theta \cdot W \cdot Ns\,;\ \theta < 1$ 7. $C_d = \alpha_1 \cdot YD + \alpha_2 \cdot H_{h-1}\,;\ 0 < \alpha_2 < \alpha_1 < 1$ 8. $\Delta H_s = H_s - H_{s-1} = G_d - T_d\ (Financial\ assets - supply\ flow$ 9. $\Delta H_h = H_h - H_{h-1} = YD - C_d\ (Financial\ assets - holding\ flow)$ 10. $Y = C_s + G_s$ 11. $N_d = \frac{Y}{W}$	YD is the disposable income of households , its equal to nominal wage rate W times labor supplied minus taxes supplied, T_d are the taxes demanded by the government and they are equal to θ personal income tax rate times nominal wage rate times labor supply; personal tax rate is lower than 1. C_d is the consumption demand by the households and equals α_1 propensity to consume out of regular income times disposable income plus α_2 propensity to consume out of past wealth times H_{h-1} cash money held by households in previous period. ΔH_s is the change in the high powered money and it is equal to G_d services supplied to and demanded by the government and taxes demanded by the government; ΔH_h is the change in money held by the households it is equal to disposable income minus consumption demanded by the households. Y is the national income and it equals to C_s consumption goods supplied by the firms and G_s services supplied by the government. N_d demand for labor is equal to the ratio between national income and nominal wage rate.
$\Delta H_h = \Delta H_s$	This is the redundant or hidden equation. Change in the cash money held by the households equals to change in the cash money supplied to households by the central bank

Source: Godley and Lavoie (2007a)

Table 2 Parameters for the model with government money for $T = 100$ periods

Parameters	**Symbols**	**Values to change**
Tax rate	θ	20%
Propensity to consume (income)	α_1	0.6
Propensity to consume (wealth)	α_2	0.4
Public expenditures	G	20

Table 3 Steady state solutions for $G = 20$

Steady-state solutions	**Symbols**	**Values**
Public expenditures	G*	20
National Income	$Y^* = \frac{G^*}{\theta}$	100
Taxes	$T^* = \theta \times Y^*$	20
Disposable Income	$YD^* = C^* = \frac{G^*(1-\theta)}{\theta}$	80
Consumption	$C^* = \alpha_1 \times YD^* + \alpha_2 \times H_{-1}$	80
Change in cash (Gov.)	$\Delta Hs^* = G^* - T^*$	0
Change in cash (hous.)	$\Delta Hh^* = YD^* - C^*$	0
Wealth	$H^* = \alpha_3 \times G^* \times \frac{1-\theta}{\theta}$	80

Source: Authors' calculation

In previous table $\alpha_3 = \frac{1-\alpha_1}{\alpha_2}$.Behavioral transactions matrix for the simple model with government money is given as:

Table 4 Transactions matrix for the model with government money

	Household	Production	Government	$\sum$
Consumption	$-C_d$	$+C_s$		0
Government expenditures		$+G_s$	$-G_d$	0
Output		Y		
Factor income	$+W \times N_s$	$-W \times N_d$		0
Taxes	$-T_s$		$+T_d$	0
Changes in stock of money	$-\Delta H_h$		$+\Delta H_s$	0
$\sum$	0	0	0	0

Source: Godley and Lavoie (2007a)

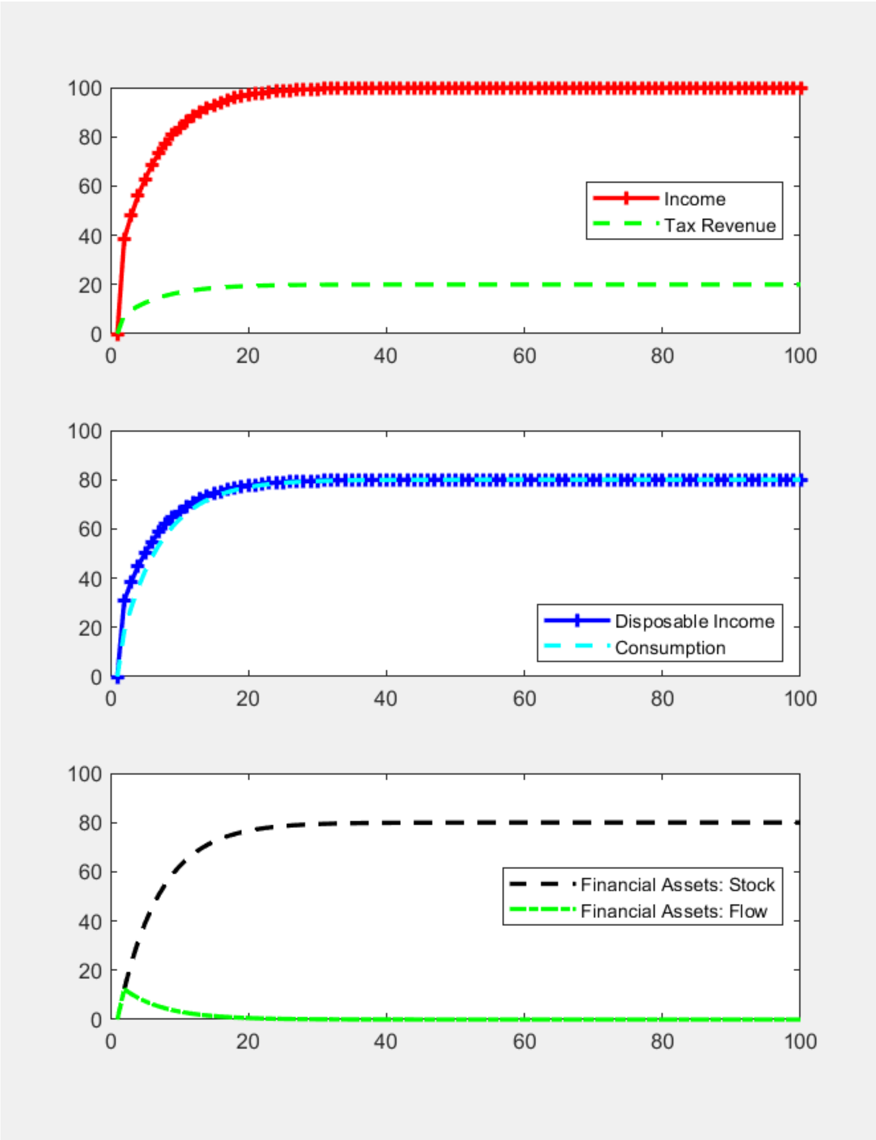
Standard Keynesian multiplier is derived from the textbook consumption function which is given as: $C_d = \alpha_1 \cdot YD$ and $Y = C + G = \alpha_1 \cdot [Y \cdot (1-\theta)] + G$, with a perfect foresight national income in the consumption function must be identical to the national income as defined in production:

equation 5

$$Y^* = \frac{G}{1 - \alpha_1 \cdot (1-\theta)}$$

For out values $\frac{1}{1-\alpha_1 \cdot (1-\theta)} = 1.92$. Next are presented the results for the simple Post-keynesian stock flow model with government money.

Figure 1 Simulation in Matlab for $T = 100$ simple model with government money



Next it will be presented simple model with government money that is Post-Keynesian though it contains expectations. Three distinctive equations to the previous model are as follows:

equation 6

$$C_d = \alpha_1 \cdot YD^e + \alpha_2 \cdot H_{h-1}\,; 0 < \alpha_2 < \alpha_1 < 1 \text{ (the new consumption function)}$$

equation 7

$$\Delta H_d = H_d - H_{h-1} = YD^e - C_d \text{ (the demand for money)}$$

equation 8

$$YD^e = YD_{-1} \text{ (expected disposable income)}$$

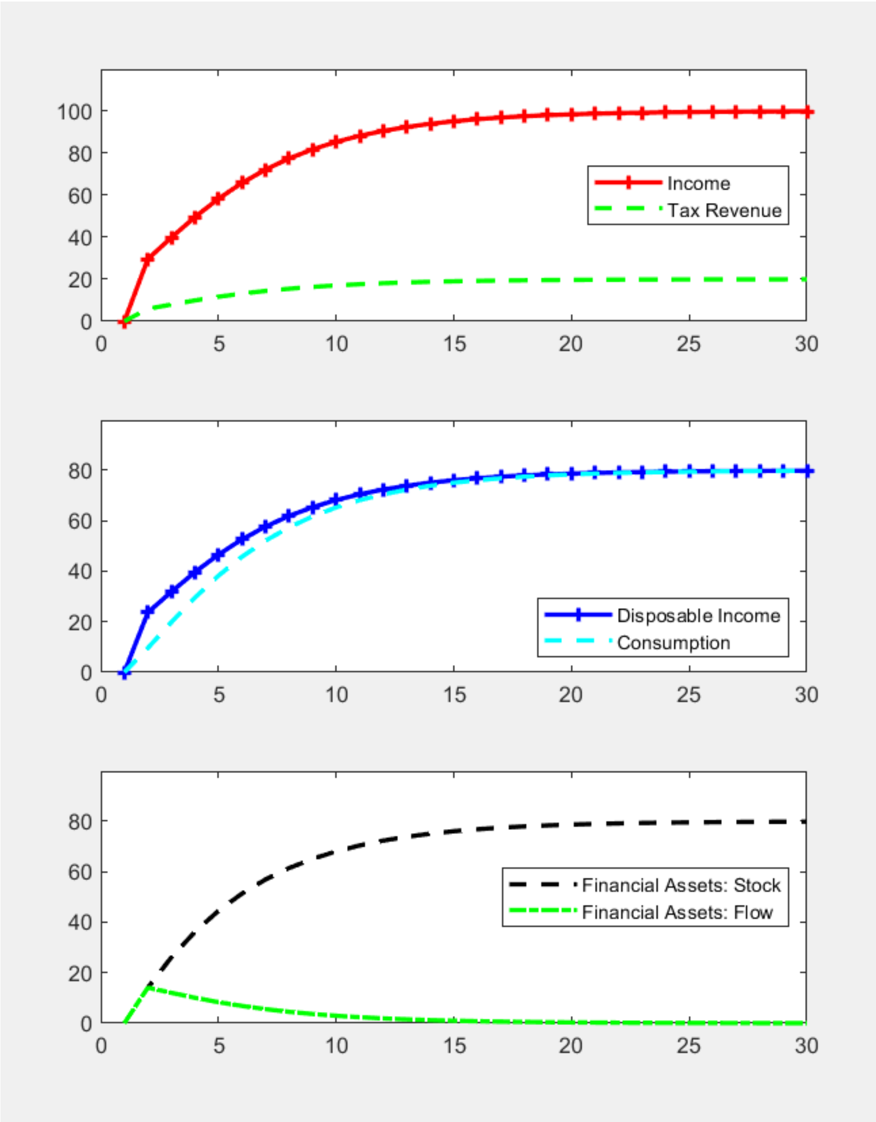
Where YD^e is the expected disposable income, H_d are the cash money held by the households. To the extent that expectations about the disposable income are altered or misleading, The end period stock of money must differ to an equal extent from what was initially demanded so subtracting $\Delta H_d = H_d - H_{h-1} = YD^e - C_d$ with $\Delta H_h = H_h - H_{h-1} = YD - C_d$ gives :

equation 9

$$H_h - H_d = YD - YD^e$$

The above equation shows that if realized income is above expected income, then the households will hold the difference in the form of larger than expected cash money balances. The model is plotted below.

Figure 2 Simulation in Matlab for T=100 simple model with government money and expectations



Next some fomalities abot the PK-SCF model with misleading expectations are presented.

Table 5 Transaction matrix for the model with government money with misleading expectations

	Household	Production	Government	$\sum$
Consumption	$-C_d$	$+C_s$		0
Government expenditures		$+G_s$	$-G_d$	0
Output		Y		
Factor income	$+W \times N_s^e$	$-W \times N_d$		$W \times N_s^e - W \times N_d$
Taxes	$-T_s^e$		$+T_d$	$T_d - T_s^e$
Changes in stock of money	$-\Delta H_d$		$+\Delta H_s$	$\Delta H_s - \Delta H_d$
$\sum$	0	0	0	0

Source: Godley and Lavoie (2007a)

The households are assumed to make mistakes only but their column at the end must be equal to zero, if not the plans of the households would be incompatible with the budget constraint. Parameters for this model are the same as in previous. The solution for the Y in all situations here can be obtained by putting consumption function back into national income identity to obtain the difference equation:

equation 10

$$Y = \frac{G + \alpha_2 \cdot H_{-1}}{1 - \alpha_1 \cdot (1 - \theta)}$$

The analogue solution for the stock of money in every intermediate situation in this perfect fore sight model is given as:

equation 11

$$H_h = (1 - \alpha_1) \cdot (1 - \theta) \cdot Y + (1 - \alpha_2) \cdot H_{-1}$$

Simple difference equation for H and H_{-1} is given as:

equation 12

$$H = \frac{G \cdot (1 - \alpha_1) \cdot (1 - \theta)}{1 - \alpha_1 \cdot (1 - \theta)} + H_{-1} \cdot \left(\frac{1 - \alpha_1 \cdot (1 - \theta) - \alpha_2 \cdot \theta}{1 - \alpha_1 \cdot (1 - \theta)}\right)$$
$$= \frac{G \cdot (1 - \alpha_1) \cdot (1 - \theta)}{1 - \alpha_1 \cdot (1 - \theta)} + H_{-1} \cdot \left(\frac{1 - \alpha_1 \cdot (\alpha_2 - \alpha_1) \cdot \theta)}{1 - \alpha_1 \cdot (1 - \theta)}\right)$$

The time for the effects of the change in government expenditure to take place can be determined with a theorem known as mean lag theorem[12]:

equation 13

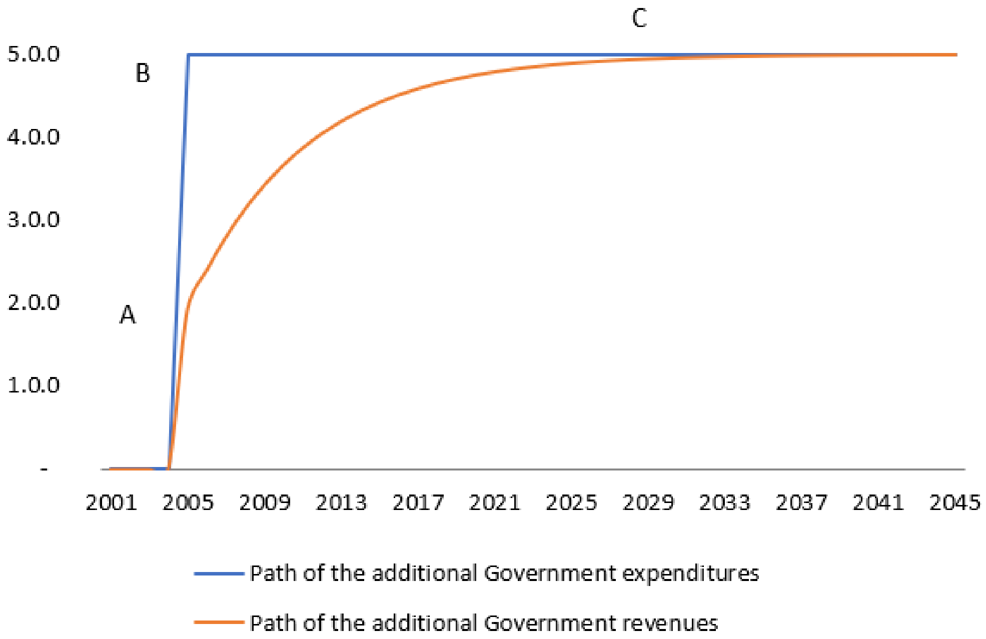
$$Ml = \alpha_3 \cdot \Delta G \cdot \frac{\left(\frac{1 - \theta}{\theta}\right)}{\Delta G} = \alpha_3 \cdot \frac{1 - \theta}{\theta}$$

On the next plot the area ABC, whatever the shape of the response of the tax flow, is equal to the addition to government debt during the whole period between the two steady states (during each of which debt is not changing and therefore $G = T = \theta \cdot Y$).The change is 5 it starts with government expenditures equal to 5.The change in debt between steady-states is given as:$\alpha_3 \cdot \Delta YD = \alpha_3 \cdot$

[12]The mean lag theorem or that the mean lag of spending behind income equals the steady-state ratio of money stock to income,see Godley and Cripps (1983).

$(1-\theta)\Delta Y$. But $\Delta YD = \frac{\Delta G}{\theta}$ so the area $ABC = \alpha_3 \cdot \Delta G \cdot (1-\theta)\Delta Y$. The mean lag is the area ABC divided by the line AB.

Figure 3 Mean lag theorem for the effects of the increase in government expenditures



For example : $\alpha_3 = 1, \theta = 0.2$, and $(1-\theta) = 0.8$, so that the mean lag is equal to $1(0.8)/(0.2) = 4$. With the tax rate at 40%, the mean lag would only be 1.5 periods. Before we proceed with the Long-term bonds' capital gains liquidity preferences model we will explain in short the mentioned perfect foresight and Lucas critique.

3.1 Lucas critique

Lucas critique is due to Lucas (1976)[13] .The essence of the Lucas critique is as follows:

equation 14

$$AD: m + v = p + y$$

Where m-Money (the log of) the money supply; v-velocity assumed to be constant ; p-price level; y-output GDP and:

equation 15

$$p = p^e + \lambda(y - y^*)$$

p^e-expected price level; λ-slope of the AS curve . If λ is large, an increase in output above potential output causes a steep rise in prices above what had been expected. If λ is small, the short-run response of prices to output is small.

[13] Lucas (1976) argued that the parameters of traditional macroeconometric models depended implicitly on agents' expectations of the policy process and were unlikely to remain stable as policymakers changed their behavior,see Rudebusch (2002).

equation 16

$$y = \frac{1}{1+\lambda}m + \frac{1}{1+\lambda}(v - p^e) + \frac{\lambda}{1+\lambda}y^*$$

equation 17

$$p = \frac{\lambda}{1+\lambda}(m + v - y^*) + \frac{1}{1+\lambda}p^e$$

And $MV = PY \Rightarrow \ln(PY) \Rightarrow lnM + lnV = lnP + lnY \Rightarrow m + v = p + y$; $\lambda = \frac{1}{2}$.So that,

$\uparrow m \approx 1\%$ $\uparrow y \approx \frac{1}{1+\lambda}$ $\uparrow p \approx \frac{\lambda}{1+\lambda}$. Let's suppose $\lambda = \frac{1}{2}$ $y = \frac{1}{1+\lambda} = \frac{1}{1+\frac{1}{2}} = \frac{2}{3}$; $p = \frac{\lambda}{1+\lambda} = \frac{\frac{1}{2}}{1+\frac{1}{2}} = \frac{1}{3}$; $m = 2; v = 3; y^* = 4; p^e = 5$. What would be the price level?

equation 18

$$y = \frac{1}{1+\lambda}m + \frac{1}{1+\lambda}(v - p^e) + \frac{\lambda}{1+\lambda}y^* \Rightarrow \frac{2}{3} \times 2 + \frac{2}{3}(3-5) + \frac{1}{3} \times 4 = \frac{4}{3} - \frac{4}{3} + \frac{4}{3} = \frac{4}{3}$$

equation 19

$$p = \frac{\lambda}{1+\lambda}(m + v - y^*) + \frac{1}{1+\lambda}p^e \Rightarrow \frac{1}{3}(2+3-4) + \frac{2}{3} \times 5 = \frac{1}{3} + \frac{10}{3} = \frac{11}{3} = 3\frac{2}{3}$$

This is the essence of the Lucas critique: The standard aggregate supply–aggregate demand model assumes that economic agents make predictions for the economy that are inconsistent with the predictions the model itself makes. Economic policy makers change price expectation to (they accept our forecast) $p^e = 3\frac{2}{3}$ so now:

equation 20

$$y = \frac{1}{1+\lambda}m + \frac{1}{1+\lambda}(v - p^e) + \frac{\lambda}{1+\lambda}y^* \Rightarrow \frac{2}{3} \times 2 + \frac{2}{3}\left(3 - 3\frac{2}{3}\right) + \frac{1}{3} \times 4 = 2\frac{2}{9}$$
$$\Rightarrow \frac{4}{3} + \frac{2}{3}\left(3 - \frac{11}{3}\right) + \frac{4}{3} = \frac{8}{3} + \frac{2}{3}\left(-\frac{2}{3}\right) = \frac{8}{3} - \frac{4}{9} = \frac{24-4}{9} = \frac{20}{9} = 2\frac{2}{9}$$

equation 21

$$p = \frac{\lambda}{1+\lambda}(m + v - y^*) + \frac{1}{1+\lambda}p^e = \frac{1}{3}(2+3-4) + \frac{2}{3} \times 3\frac{2}{3} = \frac{1}{3} + \frac{2}{3} \times 3\frac{2}{3} = \frac{1}{3} + \frac{22}{9} = \frac{25}{9} = 2\frac{7}{9}$$

3.3 Perfect foresight model

This model is represented as follows: $p^e = p$ expected price is equal to actual price

equation 22

$$p^e\left(1 - \frac{1}{1+\lambda}\right) = \frac{\lambda}{1+\lambda}(m - v + y^*) \Rightarrow p^e\left(1 - \frac{1}{1+\lambda}\right) \times 1 + \lambda = \frac{\lambda}{1+\lambda}(m - v + y^*) \times 1 + \lambda$$
$$\Rightarrow p^e = m - v + y^*$$

equation 23

$p^e = p = \frac{\lambda}{1+\lambda}(m - v + y^*) + \frac{1}{1+\lambda}p^e$; $p^e = p = m - v + y^*$; $y = y^*$

Notation is same as previous. And if $\uparrow m \approx 1\%$ $\uparrow y \approx \frac{1}{1+\lambda}$ $\uparrow p \approx \frac{\lambda}{1+\lambda}$ t under perfect foresight a 1 percent increase in the money supply leads to exactly a 1 percent increase in the price level. But under perfect foresight a 1 percent increase in the money supply leads to no increase at all in output. Under perfect foresight, monetary policy is neutral in the short run as well as in the long run.

4. Long term bonds capital gains liquidity preferences

Next, we will do simulation on the LP (liquidity preferences) model as per Godley, Lavoie(2007a). First the equation matrix will be presented for this model.

Table 6 Equations for the LP model

Equation	Explanation
1. $Y = C + G$ 2. $YD_r \equiv Y - T + r_{b-1} \cdot B_{h-1} + BL_{h-1}$ 3. $T = \theta \cdot (Y + r_{b-1} \cdot B_{h-1} + BL_{h-1});\ \theta < 1$ 4. $V \equiv V_{-1} + (YD_r - C) + CG$	First equation is the output equal to consumption supply by the firms and government consumption; second equation is about the regular disposable income Y_{dr} equal to labor taxes times output plus; $r_{b-1} \cdot B_{h-1}$ interest payments on bills plus BL_{h-1} long term bonds held by the households. And the fourth equation is about the wealth of households in nominal terms it is equal to the past wealth V_{-1} the diff. between regular disposable income minus consumption $+CG$ capital gains.
5. $CG = \Delta p_{bL} \cdot BL_{h-1}$ 6. $C = \alpha_1 \cdot YD_r^e + \alpha_2 \cdot V_{-1};\ 0 < \alpha_2 < \alpha_1 < 1$ 7. $V^e \equiv V_{-1} + (YD_r^e - C) + CG$ 8. $H_h = V - B_h - p_{bL} \cdot B_{Lh}$ 9. $H_d = V^e - B_d - p_{bL} \cdot B_{Ld}$	Fifth equation is about the capital gains equal to change in price of long-term bonds (perpetuities) times long term bonds held by the households. Consumption supplied by the firms equals α_1 propensity to consume out of regular income times expected regular disposable income plus propensity to consume out of past wealth times past wealth. Expected wealth equals past wealth plus the diff. between expected regular disposable income minus consumption plus capital gains. H_h cash money held by the households equals wealth of the household minus bills held by the household minus price of long-term bonds (perpetuities) times long term bonds held by the households. Demand for cash money held by households equals expected wealth minus Bills demanded by households (ex ante) B_d minus price of long-term bonds (perpetuities) p_{bL} times Long-term bonds demanded by households B_{Ld}

Table 7 Equations for the LP model (contd. From Table 6)

Equation	Explanation
10. $\frac{H_d}{V^e} = \lambda_{10} + \lambda_{12} \cdot r_b + \lambda_{13} \cdot ERr_{bL} + \lambda_{14} \cdot \left(\frac{YD_r^e}{V^e}\right)$ 11. $\frac{B_d}{V^e} = \lambda_{20} + \lambda_{22} \cdot r_b + \lambda_{23} \cdot ERr_{bL} + \lambda_{24} \cdot \left(\frac{YD_r^e}{V^e}\right)$ 12. $\frac{BL_d \cdot p_{bL}}{V^e} = \lambda_{30} + \lambda_{32} \cdot r_b + \lambda_{33} \cdot ERr_{bL} + \lambda_{34} \cdot \left(\frac{YD_r^e}{V^e}\right)$ 13. $B_h = B_d$ 14. $BL_h = BL_d$	First equ. Is the demand for cash money held by households divided by the expected wealth; lambdas are the reaction parameters as per Tobin (1969) and will be presented later under this table. ERr_{bL} is the expected return on the long term bonds, $\frac{YD_r^e}{V^e}$ is the ration between expected disposable regular income and expected wealth; $\frac{BL_d \cdot p_{bL}}{V^e}$ represents the ratio between long term bonds demanded by the households times their price price of long-term bonds (perpetuities) P_{bL} .Equations 13 and14 represent the equilibrium between long term bonds demanded and held by the households.
15. $\Delta B_s \equiv B_s - B_{s-1} \equiv (G + r_{b-1} \cdot b_{s-1} + BL_{s-1}) - (T + r_{b-1} \cdot B_{cb-1}) - \Delta BL_s \cdot p_{bL}$ 16. $\Delta H_s \equiv H_s - H_{s-1} \equiv \Delta B_{cb}$ 17. $B_{cb} = BL_h$ 18. $ER_{bL} = r_{bL} + \chi \cdot \frac{(p_{bL}^e - p_{bL})}{p_{bL}}$ 19. $r_{bL} = \frac{1}{p_{bL}}$ 20. $p_{bL}^e = p_{bL}$	Eq.15 here is about the change in Treasury bills supplied by government ; other symbols here G are Pure government expenditures in nominal terms; $B_{cb} = BL_h$ says that long-term bonds held by the households should equal to Bills held by the central bank. r_{bL} are the yield on long term bonds which are inversely proportional to Price of long-term bonds (perpetuities); ER_{bL} are the expected rate of return on long-term bonds equal to yield on long-term bonds plus Weight of conviction in expected bond prices (durability of bonds).Change in high-powered money ΔH_s should equal to change in Bills held by the central bank$\equiv \Delta B_{cb}$(be equivalent)
21. $CG^e = \chi \cdot (p_{bL}^e - p_{bL}) \cdot B_{L_h}$ 22. $YD_r^e = YD_{r-1}$ 23. $r_b = \bar{r}_b$ 24. $p_{bL} = \bar{p}_{bL}$ 25. $H_s = H_h$	Eq.21 is about expected capital gains in the current period equals to Weight of conviction in expected bond prices (durability of bonds) χ weighted product of the expected change in bond prices (relative to the bond price of the current period) times diff.between expected and the actual price of long -term bonds times long-term bonds held by the households.
26. $\Delta p_{bL}^e = -\beta(p_{bL-1}^e - p_{bL}) + \varepsilon$ 27. $p_{bL} = (1 + z_1 \cdot \beta - z_2 \cdot \beta) \cdot p_{bL-1}$ 28. $z_1 = 1$ if $TP > top$ 29. $z_2 = 1$ if $TP < bottom$ 30. $TP = \frac{BL_{h-1} \cdot p_{bL-1}}{BL_{h-1} \cdot p_{bL-1} + B_{h-1}}$	The price of bonds depends on whether a certain target proportion, here called TP, is kept within its target range. The proportion TP is the ratio of the value of long-term bonds outstanding to the total value of bonds and bills in the hands of households. When the targeted proportion exceeds the top of the range, called top, the Treasury lets bond prices float upwards. When the targeted proportion falls below the bottom of the range, called bot, the Treasury lets bond prices float downwards.In the evolution of change in bond prices equationΔp_{bL}^e; β represents Reaction parameter related to expectations and ε is the random error term

Source: Godley and Lavoie (2007a)

Tobin (1969) underlined five conditions vertical conditions that must hold:

equation 24

$$\lambda_{10} + \lambda_{20} + \lambda_{30} = 1$$

equation 25

$$\lambda_{11} + \lambda_{21} + \lambda_{31} = 0$$

equation 26

$$\lambda_{12} + \lambda_{22} + \lambda_{32} = 0$$

equation 27

$$\lambda_{13} + \lambda_{23} + \lambda_{33} = 0$$

equation 28

$$\lambda_{14} + \lambda_{24} + \lambda_{34} = 0$$

Eq.25 means that the total of the shares of each asset must sum to unity, whatever the actual values taken by the rates of return and disposable income. All these lambdas are reaction parameters in the portfolio choice of households. Next, equations imply that the vertical sum of the coefficients in the matrix must sum to zero. For instance, the last equation 29 implies that the response of assets in total to a change in disposable income is zero[14].

Table 8 Integration of household stock and flow accounts , within the model with liquidity preferences (LP)

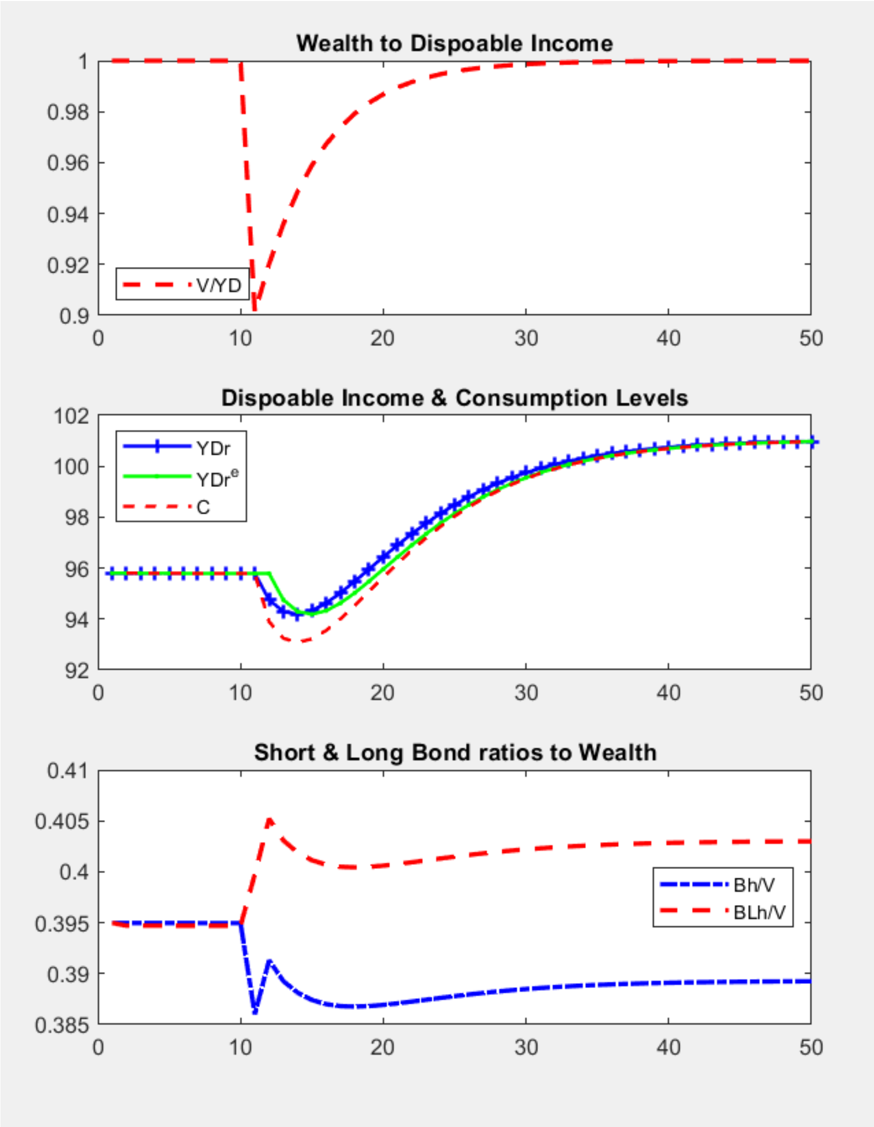
		Money	Bills	Bonds	$\sum$ assets
Initial assets (end of previous period)		H_{h-1}	$B_{(h-1)}$	$p_{bL-1} \cdot BL_{h-1}$	V_{-1}
Consumption	$-C$				0
Income =GDP	$+Y$				0
Interest payments on bills	$+r_{b-1} \cdot B_{h-1}$				0
Interest payments on bonds	$+BL_{h-1}$				0
Taxes	$-T$				0
Change in money	$-\Delta H_h$	$+\Delta H_h$			0
Change in bills	$-\Delta B_h$		$+\Delta B_h$		0
Change in bonds	$-\Delta BL_h \cdot p_{bL}$			$+\Delta BL_h \cdot p_{bL}$	0
$\sum$	0	H_h	B_h	$p_{bL-1} \cdot BL_{h-1} + \Delta BL_h \cdot p_{bL}$	$H_h + B_h + \Delta BL_h \cdot p_{bL} + p_{bL-1} \cdot BL_{h-1}$
Capital gains				$+\Delta p_{bL} \cdot BL_{h-1}$	$+\Delta p_{bL} \cdot BL_{h-1}$
Final assets		H_h	B_h	$p_{bL} \cdot BL_h$	

Source: Godley and Lavoie (2007a)

The model is plotted below.

[14] Horizontal constraints are: $\lambda_{11} = -(\lambda_{12} + \lambda_{13})$; $\lambda_{22} = -(\lambda_{21} + \lambda_{23})$; $\lambda_{33} = -(\lambda_{31} + \lambda_{32})$

Figure 4 Long term bonds capital gains liquidity preferences



5. Inside and outside money

This is a complete model with inside and outside money. In monetary economics, inside money is money issued by private intermediaries (i.e. commercial banks) in the form of debt (credit). Inside money is liability in a form of negative asset to the issuer, and the net amount of assets associated with the inside money in the economy is zero. Outside money are not liability to anyone in the economy. It is held in net positive amounts. This model is more complex and now equations should describe four sections of the economy, namely: firms, households, government (central bank); and commercial banks. In the model superscript "t" means target, superscript "e" means expected, "d" subscript is demanded, "h" subscript is realized. And all of the variables without subscript are realized values. In what follows equations of the model are presented:

Table 9 Firms equations

Equation	Explanation
1. $y = s^e + (in^e - in_{-1}$ 2. $N = \frac{y}{pr}$ 3. $WB = N \cdot W$ 4. $UC = \frac{WB}{y}$ 5. $s^e = \beta \cdot s_{-1} + (1-\beta) \cdot s^e_{-1}$ 6. $s^e = [s_{-1} \cdot (1+\varepsilon)]$ 7. $in^t = \sigma^t \cdot s^e$ 8. $\sigma^t = \sigma_0 + \sigma_1 \cdot r_1$ 9. $r_r = \frac{(1+r_1)}{(1+\pi)} - 1$ 10. $in^e = in_{-1} + y \cdot (in^t - in_{-1}$ 11. $p = (1+\tau) \cdot (1+\varphi) \cdot nhuc$ 12. $nhuc = (1-\sigma^t) \cdot uc + \sigma^t \cdot (1+r_1) \cdot uc_{-1}$ 13. $EP^e = \frac{\varphi}{1+\varphi} \cdot \frac{1}{1+\tau} \cdot p \cdot s^e$ 14. $s = c + g$ 15. $S = s \cdot p$ 16. $in - in_{-1} = y - s$ 17. $\sigma_s = \frac{in_{-1}}{s}$ 18. $in_h = in \cdot uc$ 19. $L_d = in_h$ 20. $RP_h = S - t - WB + \Delta in - r_1 \cdot in_{-1}$ 21. $\pi = \frac{p - p_{-1}}{p_{-1}}$	y is output, s sales, in inventories (measured as physical objects); N is employment, pr productivity WB is the wage bill, W the nominal wage rate; UC is the unit cost of producing one object; $s^e$are adaptative expectations on sales, ε is random variable $\varepsilon \sim (0, \sigma^2)$ in^t are long run targeted inventories σ^t are Target (current) inventories to sales ratio and are dependent on r_1 nominal rate of loans; r_r is the Fischer discrete formula π is the inflation rate $nhuc$ are nonhistorical unit costs ; EP^e are the expected profits of the firms ; s are realized sales volume equal to consumption plus government expenditures; S are the realized sales in value in dollars \$; $in - in_{-1}$ is the change in inventories; σ_s is the realized inventories to sales ratio, L_d are the loans demanded by the firms, RP_h are the realized entrepreneurial profits for the firms, π is the rate of price inflation.

Source: Godley and Lavoie (2007a)

Table 10 Households equations

Equation	Explanation
1. $YD_r = RP + WB + r_{m-1} \cdot M2_{h-1} + r_{b-1} \cdot B_{hh-1} + BL_{h-1}$ 2. $CG = \Delta p_{bL} \cdot BL_{h-1}$ 3. $YD_{hs} = YD_r + CG$ 4. $RP = RP_f + RP_b$ 5. $\Delta V = YD_{hs} - C$ 6. $V_{nc} = V - H_{hh}$ 7. $yd_r = \frac{YD_r}{p} - \pi \cdot \frac{V_{-1}}{p}$ 8. $yd_{hs} = c + \Delta v = c + (v - v_{-1})$ 9. $yd_{hs} = \frac{YD_r}{p} - \pi \cdot \frac{V_{-1}}{p} + \Delta p_{bL} \cdot \frac{BL_{h-1}}{p}$ 10. $v = \frac{V}{p}$ 11. $c = \alpha_0 + \alpha_1 \cdot yd_r^e + \alpha_2 \cdot v_{-1}$ 12. $yd_r^e = \varepsilon \cdot yd_{r-1} + (1-\varepsilon) yd_r^e - 1$ 13. $yd_r^e = [yd_{r-1}(1+\epsilon)]$ 14. $V^e = V_{-1} + (YD_r^e - C)$ 15. $H_{hd} = \lambda_c \cdot C$ 16. $v_{nc}^e = v^e - H_{hd}$	YDr is the realized nominal regular income of households – the sum of factor income plus interest receipts. CG is the capital gain on long-term bonds; YD_{hs} is the Haig-Simmons nominal disposable income, $RP_f + RP_b$ are the realized profits from banks and firms, ΔV is the change in nominal wealth; V_{nc} is realized wealth, net of cash; H_{hh} re the cash money held by households. yd_r is realized regular disposable income, yd_{hs} is realized real Haig–Simons income; v is realized wealth,c is real consumption, that depends on expected real disposable regular income, and past real wealth; yd_r^e is expected disposable regular income, $yd_r^e = [yd_{r-1}(1+\epsilon)]$ is an alternative to previous with ϵ random variation, V^e is the expected nominal wealth, H_{hd} is the household demand for cash, v_{nc}^e is the expected nominal wealth net of cash

Source: Godley and Lavoie (2007a)

Table 11 Households' portfolio equations, based on nominal rates

Equation	Explanation
1. $\frac{M1_d}{v^e_{nc}} = \lambda_{10} + \lambda_{12} \cdot r_m + \lambda_{13} \cdot r_b + \lambda_{14} \cdot ER_{bL} + \lambda_{15} \cdot \left(\frac{yD^e_r}{v^e_{nc}}\right)$	$M1_d$ are the Checking account money deposits demanded divided by the the expected nominal wealth net of cash v^e_{nc} ;r_m is Rate of interest on deposits; ER_{bL} Expected rate of return on long-term bonds; r_b is the rate f interest on bills, $(p_{bL-1} \cdot BL_d)$ is the Price of long-term bonds (perpetuities) in previous period, times Long-term bonds demanded by households; lambdas are the reaction parameters as per Tobin (1969)[15]. $\frac{B_{hd}}{v^e_{nc}}$ are the bills demanded by the households divided by the v^e_{nc} the expected nominal wealth net of cash.
2. $\frac{M2_d}{v^e_{nc}} = \lambda_{20} + \lambda_{22} \cdot r_m + \lambda_{23} \cdot r_b + \lambda_{24} \cdot ER_{bL} + \lambda_{25} \cdot \left(\frac{yD^e_r}{v^e_{nc}}\right)$	
3. $\frac{B_{hd}}{v^e_{nc}} = \lambda_{30} + \lambda_{32} \cdot r_m + \lambda_{33} \cdot r_b + \lambda_{34} \cdot ER_{bL} + \lambda_{35} \cdot \left(\frac{yD^e_r}{v^e_{nc}}\right)$	
4. $\frac{B_{hd}}{v^e_{nc}} = \lambda_{30} + \lambda_{32} \cdot r_m + \lambda_{33} \cdot r_b + \lambda_{34} \cdot ER_{bL} + \lambda_{35} \cdot \left(\frac{yD^e_r}{v^e_{nc}}\right)$	
5. $\frac{(p_{bL-1} \cdot BL_d)}{v^e_{nc}} = \lambda_{40} + \lambda_{42} \cdot r_m + \lambda_{43} \cdot r_b + \lambda_{44} \cdot ER_{bL} + \lambda_{45} \cdot \left(\frac{yD^e_r}{v^e_{nc}}\right)$	

Source: Godley and Lavoie (2007a)

Table 12 Households' portfolio equations, based on real rates

Equation	Explanation
1. $\frac{M1_d}{v^e_{nc}} = \lambda_{10} + \lambda_{11} \cdot \left(-\frac{\pi}{1+\pi}\right) + \lambda_{12} \cdot r_{rm} + \lambda_{13} rr_b + \lambda_{14} \cdot rr_{bL} + \lambda_{15} \cdot \left(\frac{yD^e_r}{v^e_{nc}}\right)$	$M1_d$ are the checking account money deposits held by households r_{rm}Real rate of interest on term deposits; rr_b is the real interest rate on bills, and rr_{bL} is the real yield on long-term bonds. $\frac{B_{hd}}{v^e_{nc}}$ is the ratio between bills demanded by the households, and v^e_{nc} the expected nominal wealth net of cash.; rr_b is the real rate of interest on bills, $\frac{(p_{bL} \cdot BL_d)}{v^e_{nc}}$ is the price of bonds times Long-term bonds demanded by households. $-\frac{\pi}{1+\pi}$ is the negative rate of return on M1 deposits; r_{rm} is the real rate on term deposits; rr_b is the rate on bills, rr_{bL} is the real rate on long-term bonds. r_b is the rate on bills.
2. $\frac{M2_d}{v^e_{nc}} = \lambda_{20} + \lambda_{21} \cdot \left(-\frac{\pi}{1+\pi}\right) + \lambda_{22} \cdot r_{rm} + \lambda_{23} \cdot rr_b + \lambda_{24} \cdot rr_{bL} + \lambda_{25} \cdot \left(\frac{yD^e_r}{v^e_{nc}}\right)$	
3. $\frac{B_{hd}}{v^e_{nc}} = \lambda_{30} + \lambda_{31} \cdot \left(-\frac{\pi}{1+\pi}\right) + \lambda_{32} \cdot r_{rm} + \lambda_{33} \cdot rr_b + \lambda_{34} \cdot rr_{bL} + \lambda_{35} \cdot \left(\frac{yD^e_r}{v^e_{nc}}\right)$	
4. $\frac{(p_{bL} \cdot BL_d)}{v^e_{nc}} = \lambda_{40} + \lambda_{41} \cdot \left(-\frac{\pi}{1+\pi}\right) + \lambda_{42} \cdot r_{rm} + \lambda_{44} \cdot rr_{bL} + \lambda_{45} \cdot \left(\frac{yD^e_r}{v^e_{nc}}\right)$	
5. $-\frac{\pi}{1+\pi} = \frac{1}{1+\pi} - 1$	
6. $r_{rm} = \frac{1+r_b}{1+\pi} - 1$	
7. $rr_b = \frac{1+rr_b}{1+\pi} - 1;\ rr_{bL} = \frac{1+rr_{bL}}{1+\pi} - 1$	

Source: Godley and Lavoie (2007a)

[15] Vertical constraints are : $\lambda_{10} + \lambda_{20} + \lambda_{30} + \lambda_{40} = 1$; $\lambda_{15} + \lambda_{25} + \lambda_{35} + \lambda_{45} = 0$; $\lambda_{11} + \lambda_{21} + \lambda_{31} + \lambda_{41} = 0$; $\lambda_{12} + \lambda_{22} + \lambda_{32} + \lambda_{42} = 0$; $\lambda_{13} + \lambda_{23} + \lambda_{33} + \lambda_{4}3 = 0$; $\lambda_{14} + \lambda_{24} + \lambda_{34} + \lambda_{44} = 0$.Horizontal constraints are: $\lambda_{11} = -(+\lambda_{12} + \lambda_{13} + \lambda_{14})$; $\lambda_{22} = -(+\lambda_{21} + \lambda_{23} + \lambda_{24})$; $\lambda_{33} = -(+\lambda_{31} + \lambda_{32} + \lambda_{34})$; $\lambda_{44} = -(+\lambda_{41} + \lambda_{42} + \lambda_{43})$.

About the realized portfolio holdings following identities hold: $H_{hh} = H_{hd}$ where intentions regarding cash are realized; $B_{hh} = B_{hd}$ intentions regarding bills are fulfilled; $B_{Lh} = B_{Ld}$ intentions regarding bonds are fulfilled; $M1_{hN} = V_{nc} - M2_d - B_{hd} - p_{bL} \cdot B_{hd}$ is the notional amount of bank checking accounts people would find themselves holding; $M1_h = M1_{hN} \cdot z_1$; $z_1 = 1$ if $M1_{hN} \geq 0$; These two equations say that the bank checking deposits held are zero if they would turn out to be negative according to equation, $M2_h = M2_d \cdot z_1 + (V_{nc} - B_{hh} - p_{bL} \cdot BL_d) \cdot z_2$; $z_2 = 1$ if $M1_{hN} < 0$; if checking deposits were to be negative, households would adjust them back to zero by decreasing time deposits, z is some numerical parameter.

Table 13 The government sector equations

Equation	Explanation
1. $TR = \tau \cdot (S - T) = S \cdot \frac{\tau}{1+\tau}$ 2. $G = p \cdot g$ 3. $D = G + r_{b-1} \cdot B_{s-1} + BL_{s-1} - (T + F_{cb})$ 4. $B_s = B_{s-1} + GBR - \Delta(BL_s) \cdot p_{bL}$ 5. $B_{Ls} = B_{Ld}$ 6. $p_{bL} = \frac{1}{r_{bL}}$ 7. $r_{bL} = \bar{r}_{bL}$	TR are the realized tax revenues from sales tax S are the sales in nominal terms; T are the taxes, τ is the sales tax rate. G are the pure government expenditures in nominal terms g are the pure government expenditures in real terms, D are the public sector borrowing requirements (deficit) F_{cb} are the CB profits; $B_s = B_{s-1} + GBR - \Delta(BL_s) \cdot p_{bL}$ is the new issue of bills, p_{bL} is the price of long-term bonds is the inverse of their yield; $r_{bL} = \bar{r}_{bL}$ Means that the yield on long-term bonds is set exogenously.

Source: Godley and Lavoie (2007a)

Table 14 CB equations

Equation	Explanation
1. $H_s = B_{cb} + A_s$ 2. $H_{bs} = H_s - H_{hs}$ 3. $B_{cb} = B_s - B_{hh} - B_{bd}$ 4. $r_b = \bar{r}_b$ 5. $A_s = A_d$ 6. $r_a = r_b$ 7. $RP_{cb} = r_{b-1} \cdot B_{cb-1} + r_{a-1} \cdot A_{s-1}$	H_s are high-powered money, B_{cb} are the bills held by CB, A_s are CB advances to commercial banks; H_{bs} reserves supplied by CB to commercial banks, has two components: the supply to banks and the supply to households; B_{cb} are the bills held by CB; $A_s = A_d$ are the advances supplied by the CB and demanded by private banks, $r_a = r_b$ rate of interest on advances equals rate of interest on bills(For simplification, the rate on advances is the same as the rate on Treasury bills); , RP_{cb} are the profits by CB

Source: Godley and Lavoie (2007a)

Next the equations about the banking system will be presented.

Table 15 Commercial banks equations

Equation	Explanation
1. $B_{bdN} = M1_s + M2_s - L_s - H_{bd}$ 2. $BLR_N = \frac{B_{bdN}}{(M1_s+M2_s)}$ 3. $A_d = [bot \cdot (M1_s + M2_s) - B_{bdN}] \times z_4; z_4 = 1$ if $BLR_N < 1$ 4. $B_{bd} = A_d + M1_s + M2_s - L_s - HB_d$ 5. $BLR_N = \frac{B_{bd}}{M1_s+M2_s}$ 6. $r_m = r_{m-1} + \Delta r_m + \zeta_b \cdot \Delta r_b$ 7. $\Delta r_m = \zeta_m(z_4 - z_5)$; $z_4 = 1$ if $BLR_{N-1} < bottom$; $z_5 = 1$ if if $BLR_{N-1} > top$ 8. $RP_b = r_{1-1} + \Delta r_1 + \Delta r_b$ 9. $\Delta r_1 = \zeta_1(z_6 - z_7)$; $z_6 = 1$ if $BPM < botpm$; $z_7 = 1$ if $BPM > toppm$ 10. $BPM = \frac{(RP_b - RP_{b-1})}{(M1_{s-1}+M1_{s-2}+M2_{s-1}+M2_{s-2})}$ 11. $H_{hs} = H_{hd}$ 12. $M1_s = M1_d$ 13. $M2_s = M2_d$ 14. $L_s = L_d$ 15. $H_{bd} = \rho_1 \cdot M1_s + \rho_2 \cdot M2_s$	B_{bdN} are the bills notionally demanded by the banks, $M1_s$ is the checking account by the deposits supplied, $M2_s$ is the time or term of the deposits supplied, L_s are the loans supplied by the firms, H_{bd} are the reserves demanded by the banks. A_d are the advances demanded by the private banks, BLR_N is the bank liquidity ratio, r_m is the real rate of deposits, ζ is reaction parameter related to changes in interest rates ; B_{bd} is the actual balance sheet by the banks,$bot; top$ are the range of BLR_N or the bottom and top of the liquidity range, RP_b is the realized profit by the banks, $H_{hs} = H_{hd}$ is the cash supplied or demanded, $M1_s = M1_d$ are the checking deposits supplied by demand, $M2_s = M2_d$ are the time deposits supplied on demand, $L_s = L_d$ are the loans supplied on demand, H_{bd} are the reserve requirements by the banks, $\rho_1; \rho_2$ are the compulsory reserve ratios on bank deposits

Source: Godley and Lavoie (2007a)

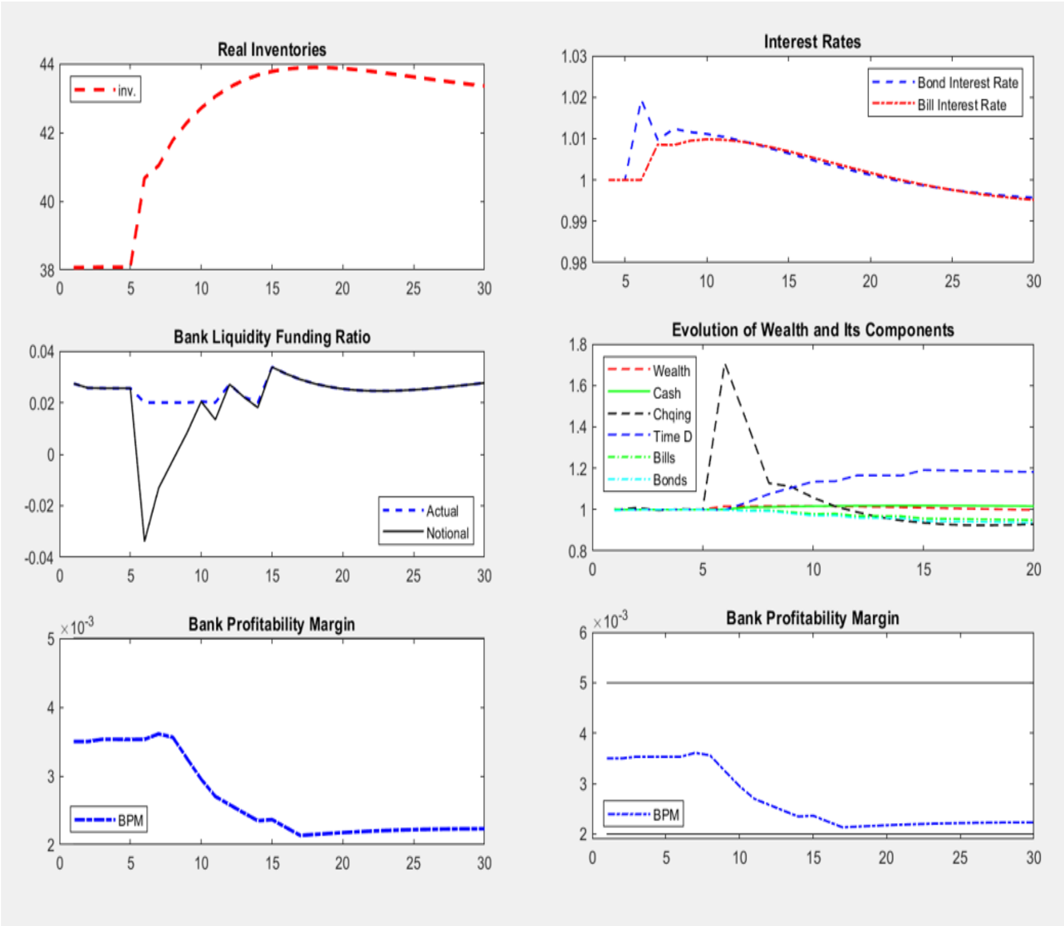
Table 16 Transaction matrix of the model with inside and outside money

			Firms			CB		Banks		Σ
		Households	current	capital	Govt.	current	Capital	current	Capital	
Consumption		$-C$	$+C$							0
Gov.expenditures			$+G$		$-G$					0
Δ in the value of inventories			$+\Delta in$	$-in$						0
Sales tax			$-T$		$+T$					0
Wages		$+WB$								0
Entrepreneurial profits		$+RP_h$	$-RP_h$							0
Bank profits		$+RP_b$						$-RP_b$		0
CB profits					$+RP_{cb}$	$-RP_{cb}$				0
Interest on	Advances					$+r_{a-1} \cdot A_{-1}$		$-r_{a-1} \cdot A_{-1}$		0
	Loans		$-r_{1-1} \cdot L_{-1}$					$+r_{1-1} \cdot L_{-1}$		0
	Deposits	$+r_{m-1} \cdot M2_{-1}$						$-r_{m-1} \cdot M2_{-1}$		0
	Bills	$+r_{b-1} \cdot B_{h-1}$			$+r_{b-1} \cdot B_{-1}$	$+r_{b-1} \cdot B_{cb-1}$		$+r_{b-1} \cdot B_{b-1}$		0
	bonds									0
Change in the stocks of	Advances						$-\Delta A$		$+\Delta A$	0
	Loans			$+\Delta L$					$-\Delta L$	0
	Cash	$-\Delta H_h$							$-\Delta H_b$	0
	Checking deposits	$-M1_h$							$+\Delta M1$	0
	Time deposits	$-M2_h$							$+\Delta M2$	0
	Bills	$-\Delta B_h$			$+\Delta B$		$-\Delta B_{cb}$		$-\Delta B_b$	0
	Bonds	$-\Delta BL_h \times p_{bL}$			$+\Delta BL \times p_{bL}$					0
Σ	0	0	0	0	0	0	0	0	0	0

Source: Godley and Lavoie (2007a)

Next inside-outside money model sim. will be plotted.

Figure 5 Model with inside and outside money



6.DSGE model (NK) -Basic RBC Model with New Keynesian Features + Sluggish prices (forward) + Inflation smoothing (backward)

In these models we will see how productivity or other shock are affecting labor supply. Standard business cycle model is very close to the canonical neo-classical growth model, this is extend the set-up with several real rigidities taken from Christiano et al. (2005) and Smets and Wouters (2003, 2007) which aim at enhancing the empirical relevance of macro-models.In this RBC model economy is populated by a large number of households $j \in [0,1]$,the utility function of a representative household is given as:

Equation 29

$$u(c_t(j), h_t(j)) = \frac{c_t(j)^{1-\sigma^c}}{1-\sigma^c} \cdot \frac{h_t(j)^{1+\frac{1}{\sigma^L}}}{1+\frac{1}{\sigma^L}}$$

Where σ^c is the risk aversion, and σ^L is the Frisch elasticity of labor supply[16]. $u(.)$ represents the utility increasing from consumption $c_t(j)$,and decreasing from hours worked $h_t(j)$. Welfare is the sum fo

[16] The Frisch elasticity measures the relative change of working hours to a one-percent increase in real wage, given the marginal utility of wealth λ .In the steady-state benchmark model is given as: $\frac{dh/h}{dw/w} = \frac{1-h}{h}\left(\frac{1-\eta}{\eta}\theta - 1\right)^{-1}$

current and expected utilities:$w_t(j) = \sum_{\tau=o}^{+\infty} \beta^{\tau} u\big(c_{t+\tau}(j), h_{t+\tau}(j)\big)$. Additionally, the production function follows a Cobb-Douglas technology:

Equation 30

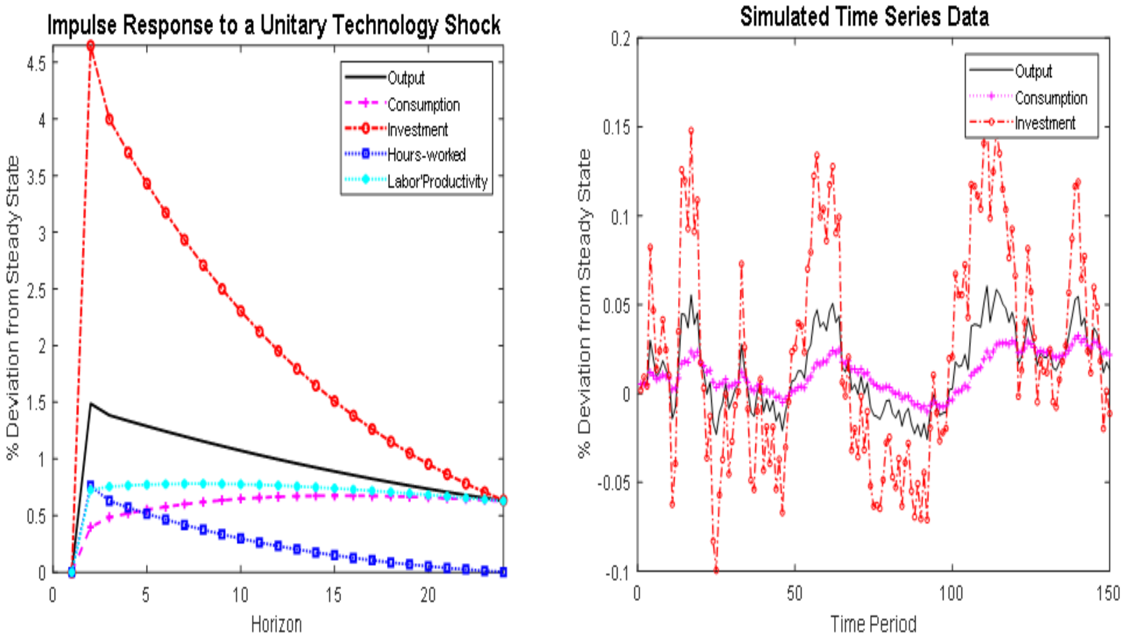
$$y_t(j) = e^{\varepsilon_t^A} h_t(j)^{1-\alpha}$$

Where $\varepsilon_t^A \sim \mathcal{N}\big(0, \sigma_{A,t}^2\big)$is an IID exogenous disturbance associated with a productivity shock. The resources constraint is given by the demand from households and authorities and it is equal to: $y_t = c_t + g^y \bar{y} e^{\varepsilon_t^G}$ .Where ε_t^G is a IDD normal shock,$\bar{y}$ is the steady-state level of GDP, and g^y is the spending to GDP ratio.

Table 17 Parameter of RBC model

parameters	α	β	δ	ψ	z	σ	ρ
Names	Capital Income Share	Subjective Discount rate	Capital Depreciation Rate	Marginal Disutility of Labor	Mean of Aggregate Technology	Standard Deviation of Technology	Autocorrelation of Technology Shocks
Values	0.36	0.99	0.025	2.0	1.0	0.007	0.95

Figure 6 Impulse Response to a Unitary Technology Shock and Simulated times series data



Typical RBC model was plotted on previous graphs. Matlab toolkit for this DSGE model was written by Haruki Seitani (2013). New-Keynesian model assumes that monopolistic competitive firms are price makers on the good market, but they cannot adjust prices as prices are sticky. For the price setting of this firms, see Calvo (1983). There is a continuum of monopolistic firms $i \in [0,1]$,that are choosing price $Pp_t^*\,(i)$. Among this firms a fraction θ^p is not a price setter, then the price remains the same $p_t^*(i) = p_{t-1}^*(j)$ .For the share of the firms $1-\theta^p$ allowed to reset their price, each firms maximizes expected sum of profits:

equation 31

$$\max_{p_t^*(j)} \sum_{\tau=0}^{+\infty} (\beta a \theta^p)^\tau \big(p_t^*(j) - MC_{t+\tau}(j)\big) y_{t+\tau}(j)$$

The FOC from the previous problem, combined with the aggregate price equation and taken in logs gives rise to the New Keynesian Phillips Curve :

Equation 32

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \frac{(1-\theta^p)(1-\beta\theta^p)}{\theta^p}(\widehat{mc}_t - \hat{p}_t)$$

Where $\widehat{mc}_t - \hat{p}_t$ are the marginal costs of the firms adjusted for inflation or additional real resources firms must spend to produce extra unit of output. Also, monetary authority controls the nominal interest rates and is concerned by both price and GDP growth. The monetary policy rule à la Taylor in logs it is:

Equation 33

$$\hat{r_t} = \rho^R\, \hat{r}_{t+1} + (1-\rho^R)(\phi_r\, \hat{\pi}_t + \phi_y(\hat{y}_t - \hat{y}_{t-1})$$

Table 18 RBC parameters

parameters	α	β	δ	σ_C	σ_L	$\frac{g}{y}$
Names	share of capital in output	discount factor	depreciation of capital	risk aversion consumption	labor disutility	Public spending to GDP
Values	0.36	0.99	0.025	1.0	2.0	0.2

Table 19 New Keynesian parameters

parameters	θ_p	ϵ_p	ρ_r	ϕ_y	ϕ_r
Names	new Keynesian Philips Curve, forward term	substitutability/mark-up on prices	Monetary Policy Smoothing Parameter	Monetary Policy GDP Growth Target	Monetary Policy Inflation Growth Target
Values	0.75	10	0.7	0.125	1.5

Next steady state equations for the NK model will be presented:

Table 20 steady-state equations NK DSGE

Equation	Explanation
1. $r = \frac{1}{\beta}$ 2. $z = \frac{1}{\beta} - (1 - \delta)$ 3. $h = \frac{1}{3}$ 4. $mc = \frac{\epsilon_{p-1}}{\epsilon_p}$ 5. $k = h\left(\frac{z}{(\alpha \times mc)^{\frac{a}{\alpha - 1}}}\right)$ 6. $y = k^{\alpha} \cdot h^{(1-\alpha)}$ 7. $c = \left(1 - \frac{g}{y}\right) \cdot y - \delta \cdot k$ 8. $I = \delta \cdot k$ 9. $w = (1 - \alpha) \cdot mc \cdot \frac{y}{h}$ 10. $\Delta c = c^{-\sigma c}$ 11. $\chi = \Delta c \cdot \frac{w}{\frac{1}{h^{\sigma_L}}}$	Steady state interest rate equals 1 over discount factor; variable z equals capital costs (or sensitivity of investment in relation to adjustment costs), h are the labor hours,mc are the marginal costs of the firms they equal /mark-up on prices form previous period divided by current markup; capital input or k or engaged physical capital equal product of labor hours times real capital costs and inversely related to the product of share of capital in output and marginal costs on the degree of elasticity of substitution of capital. y is the output and the production function is Cobb-Douglas,c consumption equals 1 minus public spending to GDP times output -depreciation δ times capital; I investment equal depreciation times capital, wage w equals 1minus share of capital in output α; times marginal costs, times productivity output divided by hours, increase in consumption is equal to inversely proportional consumption on degree of risk in consumption, χ is sensitivity of wages in relation to working hours and consumption.

Next model is plotted.

Figure 7 $VC(1,1) = 0.01^2$; *productivity shock*

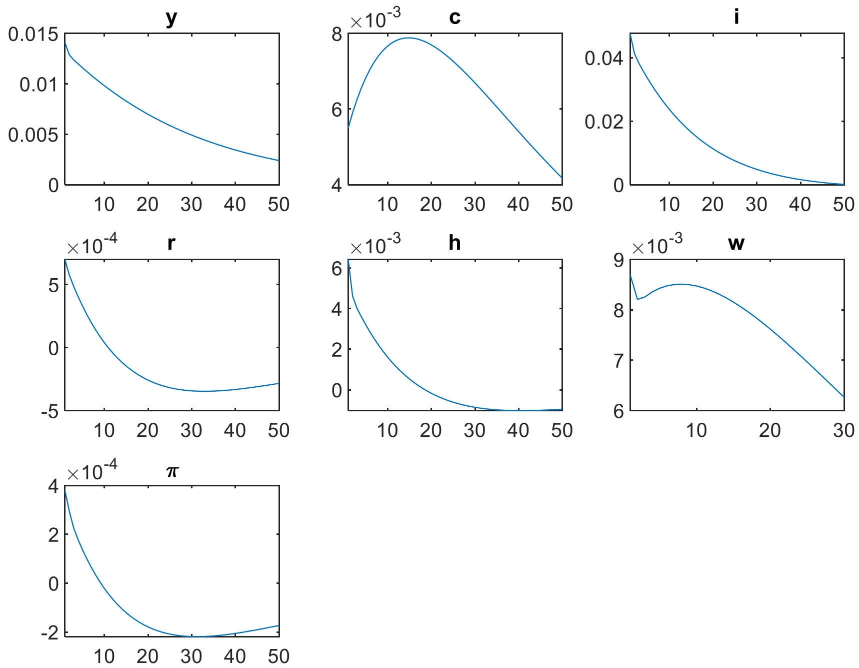


Figure 8 $VC(2,2) = 0.01^2$*; spending shock*

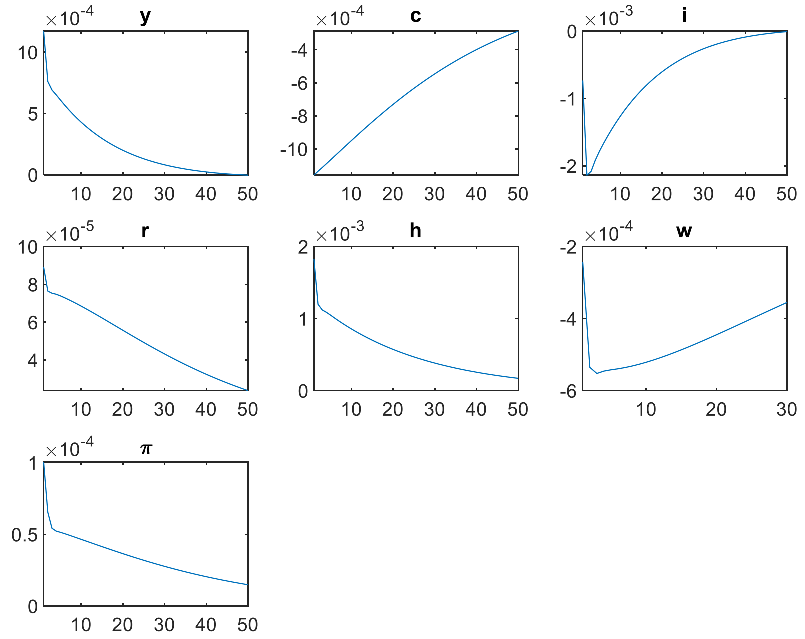
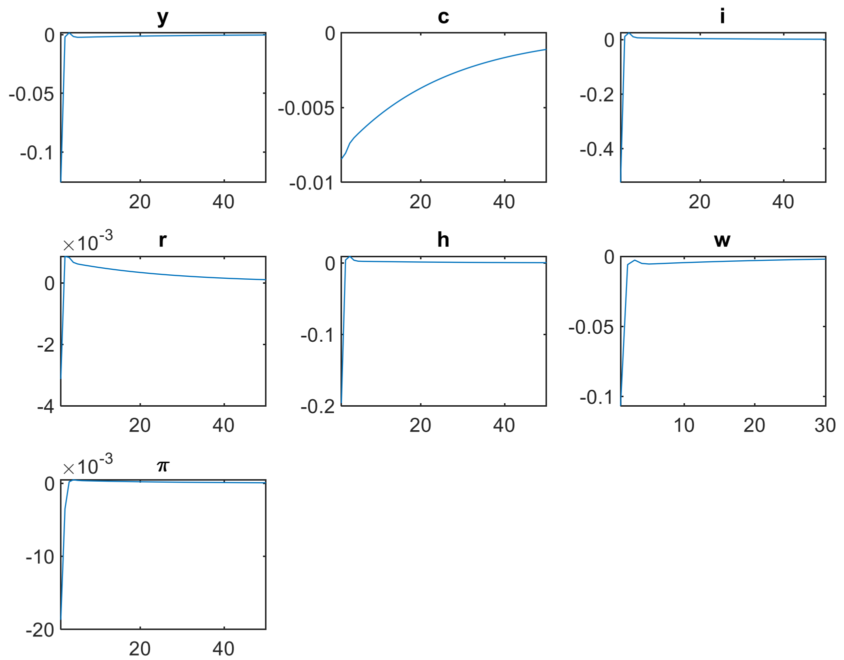


Figure 9 $VC(3,3) = 0.01^2$*; rate shock*



Source: authors calculation

8. Derivation of the New -Keynesian model (due to Eyster, Madarsz, Michaillat,(2019))

First about the fairness concerns in pricing. Price rigidity is of first order importance since it determines transmission shocks in the economy. Rotemberg (2005) developed the first theory of price rigidity based on fairness considerations, also see Rotemberg (2011). These models of fair pricing are explained in , Eyster, Madarsz, Michaillat,(2019).In the monopoly case: the markup charged by the monopoly is lower and is of size $M^p(p) = \frac{P}{\mathcal{C}^p(p)}$,where $\mathcal{C}^p(p)$ is a given by a belief function. The perceived markup determines the fairness of the transaction through a fairness function $F(M^p) > 0$. Both functions $\mathcal{C}^p(P)$ and $F(M^p)$ are assumed to be twice differentiable.Customer consumption is given as: $Z = F\big(Mp(P)\big) \cdot Y$, where a quantity Y of the good is purchased at price P. Customer faces budget constraint: $P \cdot Y + B = W$; where $W > 0$ designates initial wealth, and B designates remaining money balances. Fairness- adjusted consumption and money balances enter a quasilinear utility function : $\frac{\epsilon}{\epsilon-1} \cdot z^{\frac{\epsilon-1}{\epsilon}} + B$. Where the parameter $\epsilon > 1$ governs the concavity of the utility function. Given fairness factor F and price P, the customer chooses purchases Y and money balances B to maximize utility subject to the budget constraint. The monopoly has constant marginal cost $C > 0$. It chooses price P and output Y to maximize prots $(P - C) \cdot Y$ subject to customers' demand for its good.The demand curve is given as:$Y^d(P) = P^{-\epsilon} \cdot F\big(Mp(P)\big)^{\epsilon-1}$. The price elasticity of demand, normalized to be positive:$E = \frac{dln(Y^d)}{dln(P)} = \frac{P}{-Y^d} \cdot \frac{dY^d}{dP}$. The first-order condition then yields the classical result that:$P - \frac{E}{E-1} \cdot C$,that is, the monopoly optimally sets its price at a markup $M = \frac{E}{E-1}$ over marginal cost. To learn more about the monopoly's markup, we compute the elasticity E. Now, we find $E = \epsilon + (\epsilon - 1) \cdot \phi \cdot \left[1 - \frac{dln(\mathcal{C}^P)}{dln(P)}\right]$.

Lemma 1 When customers care about fairness, the elasticity of the fairness function

Equation 34

$$\phi(Mp) = -\frac{d\ln(F)}{d\ln(Mp)}$$

is strictly positive and strictly increasing on $(0, M^h)$with $\lim_{Mp\to 0} \phi(M^P) = 0$ and $\lim_{Mp\to M^h} \phi(M^P) = +\infty$, As an implication, the superelasticity of the fairness function:

Equation 35

$$\sigma = \frac{dln(\phi)}{d\ln(Mp)}$$

Proof .By definition,$\phi(Mp) = -Mp \cdot F'(M^p)/F(Mp)$. Using the properties of the fairness function listed in definition, $F(M^p) > 0$ and $F'(M^p) < 0$, so $\phi(Mp) > 0$. The properties also indicate that $F > 0$ is decreasing in *Mp*, and that *F*0 < 0 is decreasing in *Mp* (as *F* is concave in *Mp*). Thus, both $1/F > 0$ and $-F' > 0$ are increasing in M^p, which implies that ϕ is strictly increasing in M^p. The properties also indicate that $F(0) > 0$ and $F'(0)$ is finite, so $\lim_{Mp\to 0} \phi(M^P) = 0$. Last, the properties indicate that $F(M^h) = 0$ while $M^h > 0$ and $F'(M^h) < 0$, so that $\lim_{Mp\to M^h} \phi(M^P) = +\infty$. The final result immediately follows, as $\sigma = M^p \cdot \phi'(M^p)/\phi(M^p), \phi'(M^p) > 0$, and $\phi(M^p) > 0$■.

Now we begin the derivation of the New-Keynesian model.The household k's problem in order to be solved, first we do set up a Lagrangian:

equation 36

$$\mathcal{L}_k = \mathbb{E}_0 \sum_{t=0}^{\infty} \delta^t [\ln(Z_k(t)) - \frac{N_k(t)^{1+\eta}}{1+\eta} + \mathcal{A}_k(t)[W_k(t)N_k(t) + B_k(t-1) + V_k(t) - Q(t)B_k(t) - \int_0^1 P_j(t)Y_{jk}(t)dj] + \mathcal{B}_k(t)\left[N_k^d\left(t, W_k(t)\right) - N_k(t)\right]$$

$\mathcal{A}_k(t)$ is the Lagrangian multiplier on the budget constraint, $\mathcal{B}_k(t)$ is Lagrangian multiplier on labor demand constraint, $\eta > 0$ is the inverse Frisch elasticity of labour supply, $Z_k(t)$ is the fairness adjusted consumption index:

equation 37

$$Z_k(t) = \left[\int_0^1 Z_{jk}(t)^{\frac{\epsilon-1}{\epsilon}} dj \quad \right]^{\frac{\epsilon-1}{\epsilon}}$$

The fairness adjusted consumption is given as: $Z_{jk}(t) = F_j\left(M_j^p\left(P_j(t)\right)\right) \cdot Y_{jk}(t)$; the mark-up charged by the firms is : $M_j^p(t) = \frac{P_j(t)}{C_j^p(t)}$; F_j is the fairness function; $Y_{jk}(t)$ is the output of good each household k purchases. FOC with respect to consumption gives:

equation 38

$$\frac{\partial Z_{jk}(t)}{\partial Y_{jk}(t)} = F_j(t); \frac{\partial Z_k(t)}{\partial Z_{jk}(t)} = \left[\frac{Z_{jk}(t)}{Z_k(t)}\right]^{-\frac{1}{\epsilon}} dj$$

$j \in [0,1]$ is the continuum of firms, and the FOC for $j \in [0,1]$ implies:

equation 39

$$\left[\frac{Z_{jk}(t)}{Z_k(t)}\right]^{-\frac{1}{\epsilon}} \cdot \frac{F_j(t)}{Z_{k(t)}} = \mathcal{A}_k(t)P_j(t)$$

Taking previous expression to the power of $1-\epsilon$ we get : $\frac{1}{Z_k(t)^{1-\epsilon}} \cdot \frac{1}{Z_k(t)^{\frac{\epsilon-1}{\epsilon}}} \cdot Z_{jk}(t)^{\frac{\epsilon-1}{\epsilon}} = \mathcal{A}_k(t)^{1-\epsilon}\left[\frac{P_j(t)}{F_j(t)}\right]^{1-\epsilon}$. The prices index now will be introduced:

equation 40

$$X(t) = \left(\int_0^1 \left[\frac{P_j(t)}{F_j(t)}\right]^{1-\epsilon} dj\right)^{\frac{1}{1-\epsilon}}$$

the following is obtained: $\frac{1}{Z_k(t)^{1-\epsilon}} \cdot \frac{Z_k(t)^{\frac{\epsilon-1}{\epsilon}}}{Z_k(t)^{\frac{\epsilon-1}{\epsilon}}} = \mathcal{A}_k(t)^{1-\epsilon} \cdot X(t)^{1-\epsilon} \rightarrow \mathcal{A}_k(t) = \frac{1}{X(t) \cdot Z(t)}$ .The derivation for the output gives the following expression for all households $\forall k \in \{0,1\}$:

equation 41

$$Y_j(t) = Z(t)\left[\frac{P_j(t)}{X(t)}\right]^{\epsilon} \cdot F_j(t)^{\epsilon-1}$$

F_j fairness function is a function of a perceived mark-up, $F_j(t) = F_j\left(\frac{P_j(t)}{C_j^P(t)}\right)$; and that the perceived marginal cost $C_j^P(t)$ follow: $C_j^P(t) = \left[C_j^P(t-1)\right]^\gamma \left[\frac{\epsilon-1}{\epsilon} P_j(t)\right]^{1-\gamma}$ so that the demand function for the good j is given as:

equation 42

$$Y_j^d\left(t, P_j(t), C_j^p(t-1)\right) = Z(t)\left[\frac{P_j(t)}{X(t)}\right] F_j\left(\left(\frac{\epsilon}{1-\epsilon}\right)^{1-\gamma}\left[\frac{P_j(t)}{C_j^P(t)}\right]^\gamma\right)^{\epsilon-1}$$

Elasticities from previous are :

equation 43

$$-\frac{\partial \ln\left(Y_j^d\right)}{\partial \ln\left(P_j\right)} = \epsilon + (\epsilon-1)\gamma\phi_j\left(M_j^p(t)\right) \equiv E_j(M_j^p(t)) \; ; -\frac{\partial \ln\left(Y_j^d\right)}{\partial \ln\left(P_j\right)} = (\epsilon-1)\gamma\phi_j\left(M_j^p(t)\right) \equiv E_j(M_j^p(t)) - \epsilon$$

$\phi_j = -dln\left(F_j\right)/dlnM\binom{p}{j}$ is the elasticity of the fairness function. Moreover:

equation 44

$$\int_0^1 P_j Y_{jk} dj = X^\epsilon Z_k \int_0^1 \left(\frac{P_j}{F_j}\right)^{1-\epsilon} dj = X \cdot Z_k$$

Households allocate consumption expenditures across goods, the price of one unit of fairness-adjusted consumption index is X. In period t husehold s k hold $B_k(t)$ bonds, that purchased at period t have prices $Q(t)$, and they mature in period $t+1$. The FOC here is : $\frac{\partial \mathcal{L}_k}{\partial B_k(t)} = 0$; so: $Q_k(t)\mathcal{A}_k(t) = \delta\mathbb{E}\left(\mathcal{A}_k(t+1)\right)$, $\delta \in [0,1]$ is its time discount factor. Household k's Euler consumption function is given as:

equation 45

$$Q_t = \delta\mathbb{E}_t\left(\frac{X(t)Z_k(t)}{X(t+1)Z_k(t+1)}\right)$$

Firms problem is proposed by the following Lagrangian:

equation 46

$$\mathcal{L}_j = \mathbb{E}_0 \sum_{t=0}^{\infty} \Gamma(t)\left\{P_j(t)Y_j(t) - \int_0^1 W_k(t)N_{jk}(t)dk + \mathcal{H}_j(t)\left[Y_j^d\left(t, P_j(t), C_j^p(t-1)\right) - Y_j(t)\right] + \mathcal{I}_j\left[A_j(t)N_j(t)^\alpha - Y_j(t)\right] + \mathcal{K}_j(t)\left[C_j^P(t-1)^\gamma\left[\frac{\epsilon-1}{\epsilon}P_j(t)\right]^{1-\gamma} - C_j^p(t)\right]\right\}$$

$\Gamma(t) = \frac{\delta^t[X(0)Z(0)]}{[X(t)Z(t)]}$ is the stochastic discount factor for period t- nominal payyofs, $\mathcal{H}_j(t)$ is the Lagrange multiplier on the demand constraint in period t, $\mathcal{I}_j$ is the Lagrange multiplier on the production constraint in period t; $\mathcal{K}_j(t)$ is the Lagrange multiplier on the low of motion of marginal costs, $N_j(t)$ is the employment index:

equation 47

$$N_j(t) = \left[\int_0^1 N_{jk}(t)^{\frac{v}{v-1}} dk\right]^{\frac{v}{v-1}}$$

Here $v > 1$ is the elasticity of substitution between different labour services, $N_{jk}(t)$ is the quantity of labor services. FOC with respect to employment , $N_{jk}(t)$ for all labor services $k \in [0,1]$: $\partial L_j / \partial, N_{jk}(t)$ gives:

equation 48

$$\frac{\partial N_j(t)}{\partial N_{jk}(t)} = \left[\frac{N_{jk}(t)}{N_j(t)}\right]^{-\frac{1}{v}} dk$$

All wage rates $W_k(t)$ are given as:

equation 49

$$W_k(t) = \alpha \mathcal{J}_j(t) A_j(t) N_j(t)^{\alpha-1} \cdot \left[\frac{N_{jk}(t)}{N_j(t)}\right]^{-\frac{1}{v}}$$

$\alpha \in [0,1]$ are the marginal returns to labor or diminishing returns to labor; $A_j(t)$is the level of technology, or form previous equation: $W_k(t) = \alpha \mathcal{J}_j(t) A_j(t) N_j(t)^{\alpha-1}$ or that $N_{jk}(t) = N_j(t)\left[\frac{W_k(t)}{W(t)}\right]^{-v}$. The demand for labor services $N_k^d\big(t, W_k(t)\big) = N(t)\left[\frac{W_k(t)}{W(t)}\right]^{-v}$, where in previous $N(t) = \int_0^1 N_j(t) dj$. Moreover: $\int_0^1 W_k N_{jk} dk = W^v N_j \int_0^1 W_k^{1-v} dk = W N_j$. Firms optimally allocate wage bill across labor services, the cost of one unit of labor index is W. FOC with respect to labor and wage are :

equation 50

$$\frac{\partial \mathcal{L}_k}{\partial N_k(t)} = 0 \Rightarrow N_k(t)^\eta = \mathcal{A}_k(t) W_k(t) - \mathcal{B}_k(t)\ ; \ \frac{\partial \mathcal{L}_k}{\partial W_k(t)} = 0 \Rightarrow \mathcal{A}_k(t) N_k(t) = -\mathcal{B}_k(t) \frac{dN_k^d}{dW_k}$$

Or $\mathcal{A}_k(t) W_k(t) = \mathcal{B}_k(t) v$ form where $\mathcal{B}_k(t) = \frac{N_k(t)^\eta}{v-1}$; $W_k(t) = \frac{v}{v-1} \frac{N_k(t)^\eta}{\mathcal{A}_k(t)}$; so now the wage rate will be:

equation 51

$$\frac{W_k(t)}{X(t)} = \frac{v}{v-1} N_k(t)^\eta Z_k(t)$$

FOC with respect to output gives:

equation 52

$$\frac{\partial \mathcal{L}_j}{\partial Y_j(t)} = 0 \Rightarrow P_j(t) = \mathcal{H}_j(t) + \mathcal{I}_j(t) \Rightarrow \mathcal{H}_j(t) = P_j(t) \cdot \left[1 - \frac{W(t)/P_j(t)}{\alpha A_j(t) N_j(t)^{\alpha-1}}\right]$$

Firms marginal costs $C_j(t) = \frac{W(t)}{\alpha A_j(t) N_j(t)^{\alpha-1}}$; $\mathcal{H}_j(t) = P_j(t)\left[1 - \frac{C_j(t)}{P_j(t)}\right]$; $M_j(t) = \frac{C_j(t)}{P_j(t)}$ this is the price markup , so previous can be rewritten $\frac{\mathcal{H}_j(t)}{P_j(t)} = \frac{M_j(t)-1}{P_j(t)}$ .FOC with respect to price for firms gives:

equation 53

$$\frac{\partial \mathcal{L}_j}{\partial P_j(t)} = 0 \Rightarrow Y_j + \mathcal{H}_j(t)\frac{\partial Y_j^d}{\partial P_j} + (1-\gamma)\mathcal{K}_j(t)\frac{C_j(t)}{P_j(t)} \Rightarrow (1-\gamma)\frac{\mathcal{K}_j(t)}{Y_j(t)M_j^p(t)} = \frac{M_j(t)-1}{P_j(t)}E_j\left(M_j^p(t)\right) - 1$$

FOC with respect to perceived marginal costs

$$\frac{\partial \mathcal{L}_j}{\partial C_j(t)} = 0 \Rightarrow \mathbb{E}\left(\frac{\Gamma(t+1)}{\Gamma(t)}\mathcal{H}_j(t+1)\frac{\partial Y_j^d}{\partial C_j^p}\right) + \gamma\mathbb{E}_t\left(\frac{\Gamma(t+1)}{\Gamma(t)}\mathcal{K}_j(t+1)\frac{C_j^p(t+1)}{C_j^p(t)}\right)$$

Equation that links markup to the perceived markup :

equation 54

$$\frac{M_j(t)-1}{M_j(t)}E_j\left(M_j^p(t)\right) = 1 + \mathbb{E}_t\left(\frac{\Gamma(t+1)Y_j\,(t+1)P_j(t+1)}{\Gamma(t)Y_j(t)P_j(t)}\cdot\left(\frac{M_j(t)-1}{M_j(t)}\left[E_j(M_j^p(t+1)-(1-\gamma)\epsilon\right]-\gamma\right)\right)$$

In the equilibrium nominal interest rate is $i(t) = \ln\left(\frac{1}{Q(t)}\right)$ is determined by the bond price, inflation is $\pi(t) = \ln\left(\frac{P(t)}{P(t-1)}\right)$; the price of bonds is $Q(t) = \delta\mathbb{E}_t\left(\frac{P(t)Y(t)}{P(t+1)Y(t+1)}\right)$; real wage as a function of employment is $\frac{W(t)}{P(t)} = \frac{v}{v-1}A(t)N(t)^{\eta+\alpha}$; real marginal costs are $\frac{C(t)}{P(t)} = \frac{v}{(v-1)\alpha}N(t)^{1+\eta}$, so $N(t) = \left[\frac{(v-1)\alpha}{v}\cdot\frac{1}{M)t)}\right]^{\frac{1}{1+\eta}}$ .in equilibrium stochastic discount factor is :$\Gamma(t) = \delta^t\cdot\left(\frac{X(t)Z(t)}{X(0)Z(0)}\right)^{-1}$. Or now to simplify about the marginal costs :

equation 55

$$\frac{M_j(t)-1}{M_j(t)}E\left(M^p(t)\right) = 1 - \delta\gamma + \delta\mathbb{E}\left(\frac{M(t+1)}{M(t)}[E(M^p(t+1)-(1-\gamma)\epsilon]\right)$$

Where γ is the inference parameter, since $\widehat{m^p}(t) = \gamma\left[\hat{\pi}(t) + \widehat{m^p}(t-1)\right]$ it's the evolution of the markup, $\gamma \in [0,1]$ is the degree of underinference also for the consumption we have $C_j^p(\mathrm{t}) = \left[C_j^p(\mathrm{t}-1)\right]^\gamma\left[\frac{\epsilon-1}{\epsilon}P_j(t)\right]^{1-\gamma}$. S now the perceived markup satisfies :

equation 56

$$M^p(t) = \left(\frac{\epsilon}{\epsilon-1}\right)^{1-\gamma}\left[\frac{P(t)}{P(t-1)}\right]^\gamma[M^p(t-1)]^\gamma$$

In steady-state equilibrium we have : $\bar{Q} = \delta\cdot\frac{P(t)}{P(t+1)}$; $\bar{\imath} = \rho + \bar{\pi}$; where $\rho \equiv -\ln(\delta)$ this is the discount rate. The steady-state inflation rate is :$\bar{\pi} = \frac{(\rho-\bar{\imath}_0)}{\psi-1}$,$\psi > 1$ governs the response to interest rates to inflation. So in steady-state $\overline{(M^p}\,)^{1-\gamma} = \left(\frac{\epsilon}{\epsilon-1}\right)^{1-\gamma}\left[\frac{P(t)}{P(t-1)}\right]^\gamma$. Steady-state perceived markup is : $\overline{(M^p})= \left(\frac{\epsilon}{\epsilon-1}\right)\exp\left(\frac{\gamma}{1-\gamma}\,\bar{\pi}\right)$. Or the steady-state price markup is :

equation 57

$$\bar{M} = 1 + \frac{1}{\epsilon - 1} \cdot \frac{1}{1 + \frac{(1-\delta)\gamma}{1-\delta\gamma} \phi\left(\overline{(M^p}\right)}$$

Where $\phi(\overline{M^p}) = -F'(\overline{M^p}) \cdot \overline{M^p} / F(\overline{M^p})$ is the elasticity of fairness function, $\bar{F} = F(\overline{M^p})$ is the steady-state fairness factor, $F'(\overline{M^p}) = \theta$, θ is fairness concern. A higher θ means that a consumer grows more upset when consuming an overpriced item and more content when consuming an underpriced item.

equation 58

$$\theta = -\frac{1-\delta\gamma}{(1-\delta)\gamma} < 0\,; \theta = \frac{\epsilon}{\epsilon - 1} \cdot \frac{1-\delta\gamma}{(1-\delta)\gamma} < 0$$

Now γ influences the Philips curve :

equation 59

$$\left[\frac{1-\delta\gamma}{\gamma} + (1-\delta)\theta\right]\left[\frac{(\epsilon-1)\cdot(1-\gamma)}{\gamma} + \frac{1-\gamma}{(1-\delta)\gamma}(1-\delta)\theta\epsilon\right]$$

The slope of Philips curve is decreasing in γ . In the New Keynesian model with fairness, the perceived price markup evolves according to :$\widehat{m^p}(t) = \gamma[\hat{\pi}(t) + \widehat{m^p}(t-1)$. Accordingly, the perceived price markup is a discounted sum of lagged inflation terms:$\widehat{m^p}(t) = \sum_{s=0}^{\infty} \gamma^{s+1}\ \hat{\pi}(t-s)$. Because of its autoregressive structure, the perceived price markup is fully determined by past inflation.As a result, the short-run Phillips curve involves not only forward-looking elements—expected future inlation and employment—but also backward-looking elements—past inflation.In the New Keynesian model with fairness, the short-run Phillips curve is

equation 60

$$(1-\delta\gamma)\widehat{m^p}(t) - \lambda_1\hat{n}(t) = \delta\gamma\mathbb{E}_t\big(\hat{\pi}(t+1)\big) - \lambda_2\mathbb{E}_t\big(\hat{n}(t+1)\big)$$

Where

equation 61

$$\lambda_1 \equiv (1+\eta)\frac{\epsilon + (\epsilon-1)\gamma\,\bar{\phi}}{\gamma\bar{\phi}\bar{\sigma}}\left[1 + \frac{(1-\delta)\gamma}{1-\delta\gamma}\bar{\phi}\right]$$

$$\lambda_2 \equiv (1+\eta)\delta\frac{\epsilon + (\epsilon-1)\gamma\,\bar{\phi}}{\bar{\phi}\bar{\sigma}}\left[1 + \frac{(1-\delta)\gamma}{1-\delta\gamma}\bar{\phi}\right]$$

Hence short run equilibrium Philips curve is hybrid, including both past and future inflation rates:$(1-\delta\gamma)\sum_{s=0}^{\infty}\gamma^{s+1}\ \hat{\pi}(t-s) - \lambda_1\hat{n}(t) = \delta\gamma\mathbb{E}_t\big(\hat{\pi}(t+1)\big) - \lambda_2\mathbb{E}_t\big(\hat{n}(t+1)\big)$.In log-linear equilibrium equations are :

Table 21 Log-linearized equilibrium variables

Equation	Explanation
1. $\hat{\imath}(t) = \hat{\imath_0}\ (t) + \psi\hat{\pi}(t)$ 2. $\hat{y}(t) = \hat{a}(t) + a\hat{n}(t)$ 3. $\widehat{m}(t) = -(1+\eta)\hat{n}(t)$ 4. $\widehat{m^p}(t) = \gamma[\hat{\pi}(t) + \widehat{m^p}(t-1)$ 5. $\ln(Y_t) = \mathbb{E}_t(\ln(Y_{t+1})) + \mathbb{E}_t\big(\pi(t+1) + \rho - i(t)\big)$ or $a\hat{n}(t) + \psi\hat{\pi}(t) = a\mathbb{E}_t(\hat{n}(t+1) + \mathbb{E}_t\big(\hat{\pi}(t+1) - \hat{\imath}_0(t) - \hat{a}(t) + \mathbb{E}_t(\hat{a}(t+1)\big)$ 6. $(1-\delta\gamma)\widehat{m^p}(t) - \lambda_1\hat{n}(t) = \delta\gamma\mathbb{E}_t\big(\hat{\pi}(t+1)\big) - \lambda_2\mathbb{E}_t\big(\hat{n}(t+1)\big)$	Log deviations from steady state of output, employment, price markup, and perceived price markup. Fifth equation is the IS equation, and the sixth equation is the short-run Philips curve.

Source: Eyster, Madarsz, Michaillat,(2019)

9.Conclusion

NK-DSGE models have come to be dominant force in macroeconomics research. Since they have micro foundations some see them as a “sign that macroeconomics has become a mature science, organized around a micro founded core ..” though “ Others see them as a dangerous dead end” see Blanchard (2016). If we look up at the core of New-Keynesian DSGE models, there are three equations: an equation describing aggregate demand; an equation describing price adjustment; and a equation describing the monetary policy rule. Aggregate demand as consumption function is at odds with the empirical evidence as related to the “both the degree of foresight and the role of interest rates in twisting the path of consumption”. Though these models have evolved after the 2007-8 crisis; and substantial progress has been made since then. The advances include following: financial frictions, and heterogeneity into NK-DSGE models, *k*-level thinking, social learning, adaptive learning, etc. Mainly critics on DSGE models were due to not predicting the financial crisis 2007-8, but the cause for the financial crisis was failure across, policymakers, regulators, financial market professionals to recognize and react to the growing leverage of shadow-banking sector. While PK-SCF models where agents are identified with the main institutional sectors of the capitalist economy, the short -period behavior of these agents is described by the “period by period” balance sheet dynamics are: perfectly compatible with Keynes, they are the ideal tool for rigorous Post-Keynesian analysis on medium run, they are a crucial to the consolidation of Post-Keynesian research structure. Yet NK-DSGE models are on their way to remain central to the way macroeconomics thinks about aggregate phenomena.

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