Modeling Deposit Creation and Policy Transmission Channel via Money Market Rate – Initial Implications on Stabilization Policy –

JFRC Working Paper No. 03-2019*

Yokei Yamaguchi, M.Phil., M.Sc.
Japan Futures Research Center

Keywords: Accounting System Dynamics Macroeconomic Model; Flow of Funds; Monetary Policy; Population Dynamics

Abstract

Over-simplifications of financial system in macroeconomic models became evident particularly since the financial crisis in 2007-08. Based on Accounting System Dynamics framework, the current research develops a model of a closed economy where banking sector functions as creator of deposits through loans in contrast to the intermediation theory of banking presumed in conventional models. The model structure is extended further to incorporate monetary transmission channel through interest rate on central bank reserves, representing money market determined by its supply-demand relationship. A generic model consisting of five domestic sectors turns out to produce diverse disequilibrium dynamics consistent with stylized facts, driven by interactions of reinforcing and balancing feedback loops such as expansion of money supply under stable and low level of monetary base, short-term business cycles, temporary alleviation of GDP gap by monetary easing policy, and its limitation in fully counteracting structural deflation. The paper also discusses assumptions and corresponding limitations of the model. While exploratory in nature, simulation experiments indicate positively that the model could be applied for empirical analysis based on time-series data.

*This paper is presented at a parallel session "Money and Finance", held at the 37th International Conference of the System Dynamics Society, June 21-25th, 2019, Albuquerque, NM, USA. This work is based on the author's previous work titled: Developing an Accounting System Dynamics (ASD) Macroeconomic Model of the Stock Approach – With Emphasis on Bank Lending and Interest Rates, which was submitted to the Department of Geography at University of Bergen, Norway, as a thesis for Joint European Master Program in System Dynamics in July 2017. The current ASD Macroeconomic model is developed with Vensim, a modeling software. A complete model documentation can be accessed by the University's online library repository at: http://bora.uib.no/handle/1956/16473.

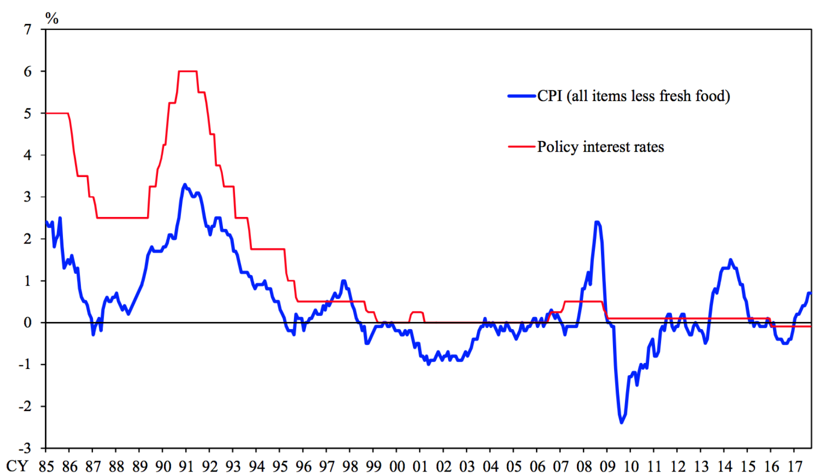
Contents

Structure of the Paper

This paper is organized as follows: it first reviews literatures and the employed methodology in Section 1. Section 2 highlights structural extensions from the base model introduced in the current research project. In Section 3, results from base run simulation are reported. Section 4 presents scenario experiments where central bank implements monetary easing policy through purchase of government bonds. Section 5 discuss limitations of the current model, and directions for improvements towards its application for case studies.

The Case of Policy Resistance in Japan

Prior to the global financial crisis in 2007-2008, economies in the U.S and United Kingdom saw declines of volatility in key macroeconomic variables [7, 2001]. These period, referred to as the Great Moderation, led economists to believe that there has been a broad "convergence in vision and methodology" [5, 2008]. The Japanese economy, on the other hand, presented a peculiar case against the general trend in macroeconomics theory. After the burst of asset price bubble in the early 90's, the economy entered into deflationary trend. Experiencing turbulent periods in the late 90's amplified by the Asian financial crisis, Bank of Japan (BOJ) continued lowering its policy rate followed by a series of asset purchase operation during 2003-06 (QE1). Under the persisting deflation and external shocks in 2007-08 crisis, BOJ expanded its asset purchase operation to an unprecedented scale in QE2 (2013-16), and introduced the negative rate policy in QE3 from 2016 onwards. The dramatic changes in monetary base induced by the asset purchase programs, however, have remained largely ineffective in achieving price stability objective of 2% inflation rate per annum, with few exceptions due to an increase in consumption tax rate in April 2014. Figure 1 shown below, adopted from Bank of Japan [28, 2017], shows historical movement of consumer price index in Japan, and changes in the policy rate since 1985, summarizing the country's long battle with the deflation.



Notes: 1. The CPI figures (y/y % chg.) are adjusted for changes in the consumption tax rate.
2. For the period when no target interest rate was adopted, figures for the policy rate are the interest rate applied on excess reserves.
Sources: Ministry of Internal Affairs and Communications; Bank of Japan.

Figure 1: Japan's Policy Rate and changes in CPI since 1985

Figure 2 below depicts behaviors of nominal GDP, monetary aggregates, bank loans, and total government debt in Japan, summarizing the macroeconomic trend since 1980. It is characterized by high economic growth in the early 1980's, formation of asset price bubbles and bursts during the late 1980's to early 90's, and stagnation starting from the late 90's. The same figure also depicts the dramatic increase in base money denoted by a red dotted line, while the government debt have grown at an exponential rate depicted by a pink line.

Much has been discussed about plausible cause of the prolonged deflation and policy ineffectiveness observed in Japan. As Koo [22, 2009] points out, a majority of literatures that have claimed the efficacy of active monetary policy are based on decades of research into the Great Depression [9, 1985] [32, 1991] [40, 1994] [2, 2000] [8, 2004]. In particular, Krugman [23, 1998] argued that a primary cause of economic difficulty is the deflation, and called for quantitative easing and inflation targeting. Bernanke [3, 2003] [4, 2004] argued for monetization of government debt under the zero-lower-bound, and Svensson [38, 2003] suggested price-level targeting and currency depreciation, which are essentially all put into practice during last decades of the economic experiment. However, the Japanese experience indicates a gap between theories and the empirical observation, and seem to provide a natural case from which we can re-examine assumptions underlying the current policy framework. Moreover, identifying factors characterizing an emergence of speculative bubble and the subsequent stagnation is of fundamental importance to the understanding and mitigation of instabilities inherent in the financial system worldwide.

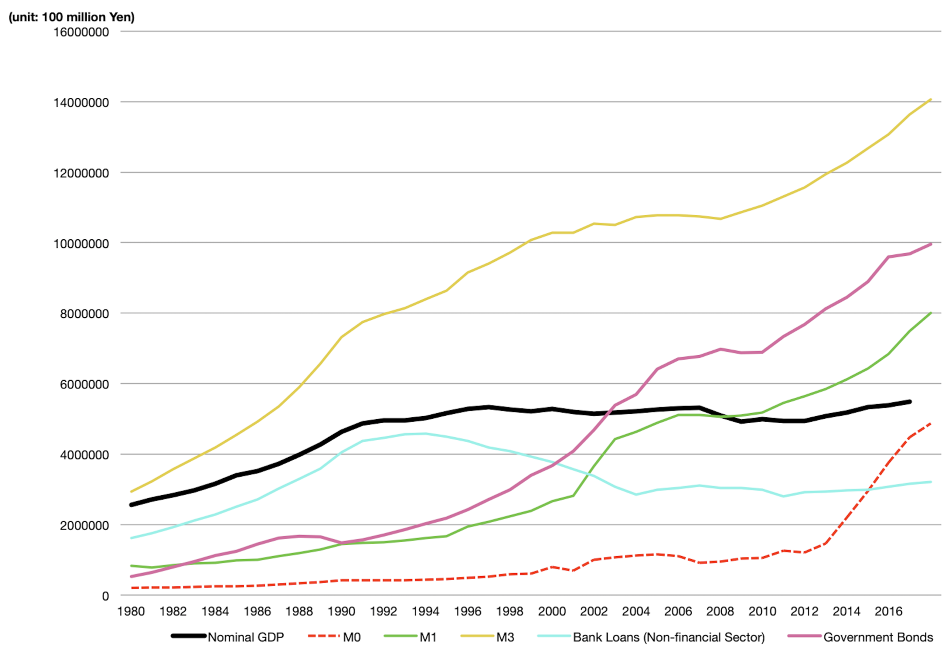


Figure 2: Behaviors of Japanese Economy since 1980

1 Literatures & Methodology

1.1 Modeling Transmission Channel of Monetary Policy

Modeling Deposit Creation theory

The role of deposit creation in macroeconomic instabilities, albeit qualitatively, have been the main subject of economists such as Mises [41, 1912], and particularly after the Great Depression in the U.S[1]. In response to the critique on econometric modeling approach by Lucas [21, 1976], developments in macroeconomic models occurded with a focus on microeconomic foundations. Subsequently, general equilibrium models, which are grounded on the theory advanced by Arrow & Debreu [1, 1954], gained popularities in theoretical research despite criticisms on unrealistic assumptions such as the neutrality of money [43, 1988].[2]

Then, the global financial crisis in 2007-08 evidenced over-simplifications of financial system presumed in Dynamic Stochastic General Equilibrium (DSGE) models, and attested limitations of their explanatory power of real-world events [6, 2010] [37, 2011]. Bank of England researchers [27, 2014] corrected the dominant view of *banks as intermediaries*, and described process of deposit creation under fractional reserve system using exemplary diagrams. Werner [42, 2016] examined how literatures in economics and finance overlooked the original and empirically-confirmed theory of deposit creation, which goes back to as early as 19th century such as Macleod [24, 1856].

The renewed understanding of the role of banking system prompted researchers to incorporate deposit creation into quantitative models as indispensable process in the economy. For example, using agent-based modeling approach, Roberto et.al [25, 2012] studies interactions of real and financial variables with a focus on the role of deleveraging behavior and endogenous credit creation. Erlingson et.al [10, 2014] investigated the role of mortgage loans in credit-based economy in agent-based simulation and demonstrated the macroeconomic instability in the presence of easy-access loans. Employing the DSGE models, Jakab & Kumhof [19, 2015] conducted a comparative analysis on the role of banks in economic cycles and showed pro-cyclical bank leverage and a significant role of credit rationing rather than price rationing during downturns.

Modeling Monetary Transmission Channel

Transmission mechanism of monetary policy is itself a model to describe channels through which policy-induced changes affect the state of economy [33, 2008] [29, 2010]. A number of different channels have been discussed and identified including asset price channel, credit channel, foreign exchange rate channel,

[1] Groups of American economists analyzed that the cause of the instability is a structural problem inherent in fractional reserve banking, and proposed 100% reserve system on transferable deposits. Such proponents include founders of the Chicago school [30, 1995], Irving Fisher [13, 1932] [12, 1933] [14, 1935] and others [15, 1939].

[2] For a critical review on unrealistic assumptions generally made in DSGE family of models, see, for example, Mahmud et.al [39, 2017] which discusses corresponding limitations stemming from their theoretical framework.

interest rate channel (list empirical literatures or review summary here). Different channels may coexist, constantly aggravating or neutralizing each other. Due to its complexity, however, it becomes challenging to incorporate them in models solved for general equilibrium. In response to emerging challenges, need for alternative modeling approaches have been increasingly recognized to study the complex dynamics characterized by feedbacks, delays and nonlinearities. Fagiolo & Roventini [11, 2017] discusses challenges of agent-based and DSGE models applied for policy analysis. Using diffusion models of contagious disease as an example, Rahmandad & Sterman [31, 2008] discuss trade-offs inherent among agent-based approach, which can capture heterogenous attributes of individuals, and differential equation models, which typically aggregates agents into compartments with different states. Given the methodological framework, choice of modeling approach should be guided, they argue, by the purpose of modeling and benefits of disaggregation as well as cognitive costs it entails.

Econometrics models generally focus on open loop event-level analysis, and have data-driven structure subject to the Lucas critique. In comparison to econometric models, system dynamics modeling in general focus on structure-behavior relationships[3], which have provided structural theories on business cycles and economic long waves [20, 1976] [16, 1977] [17, 1979] [34, 1985] [35, 1986] [18, 1989]. To the best of author's knowledge, case of monetary policy resistance have been relatively unexplored in system dynamics literatures.

1.2 Accounting System Dynamics Framework

Based on accounting system dynamics (ASD) modeling framework, Yamaguchi & Yamaguchi [45, 2016] developed two separate models to examine how the two theories on banking describe process of money creation, and demonstrated that both approaches produce nearly identical behaviors of monetary expansion and contraction. Their simulation experiments also showed the instability of money stock generated under stable and low level of base money induced by shifts in liquidity preference of household sector, and credit rationing by banking sector. However, their model structures were kept simple, leaving theoretical questions as to how endogenous expansion and contraction of money supply affects other key dynamics such as determination of GDP and price-level. Yamaguchi [44, 2013] have developed a series of macroeconomic models, which features national economic modeling. All models, however, reflects intermediation theory of banking where banking sector is assumed to make loans out of vault cash. The current research explore these theoretical questions by incorporating deposit creation theory based on the ASD framework.

[3]See generally Meadows [26, 1980] for a thoughtful discussion on differences between econometrics and system dynamics models such as operating assumptions, world views, and terminologies

2 Structure of Macroeconomic Model

2.1 Overview of Model

Current model is based on the chapter 9 model developed by Yamaguchi [44, 2013], which employs intermediation theory of banks.

2.1.1 Core Structure & Model Boundary

As in the base model, a current extended model reflects the following system structure and boundary, which are briefly explained below.

1. Fractional Reserve Banking System
2. A Closed Economy

Fractional Reserve Banking System

Most economies operates under the fractional reserve requirement regime. Table 1 below summarizes structure of fractional reserve system. A majority of base money is issued by central bank through market operations, and bank deposits, which constitute the majority of money supply, are created as interest-bearing debts.Under this system, legally required reserve ratio imposes an upper-limit to the total deposit creation within an economy, constraining the maximum loanable amount of funds by the banking sector at a particular point in time.

Monetary System under Fractional Reserve Banking	
Issuer of Currency	Government (for Coins), Central Bank (for Notes & Reserves)
Role of Banks	Creator of Deposits convertible to Bank Notes
Bank Deposits	Fractionally reserved
Issuance of Money	Base Money: Lending Facility & Market Operation by Central Bank Money Supply: Loans by Commercial Banks
Nature of Money	Interest-bearing Debt
Implementation of Policy	Monetary Policy: Central Bank Fiscal Policy: The Government

Table 1: Structure of Fractional Reserve Banking System

A Closed Economy

The model assumes a closed economy with five domestic sectors as in the base model. They are: households, producers, commercial banks, the government, and central bank. The overseas sector is excluded in the current analysis; it is assumed that no world exists outside of the model economy. Therefore, any feedback effects resulting from foreign exchange dynamics are left out. Instead, we focus on dynamics growing out of interactions among the domestic five sectors. Figure 3 below illustrates an overview of macroeconomic system reflected

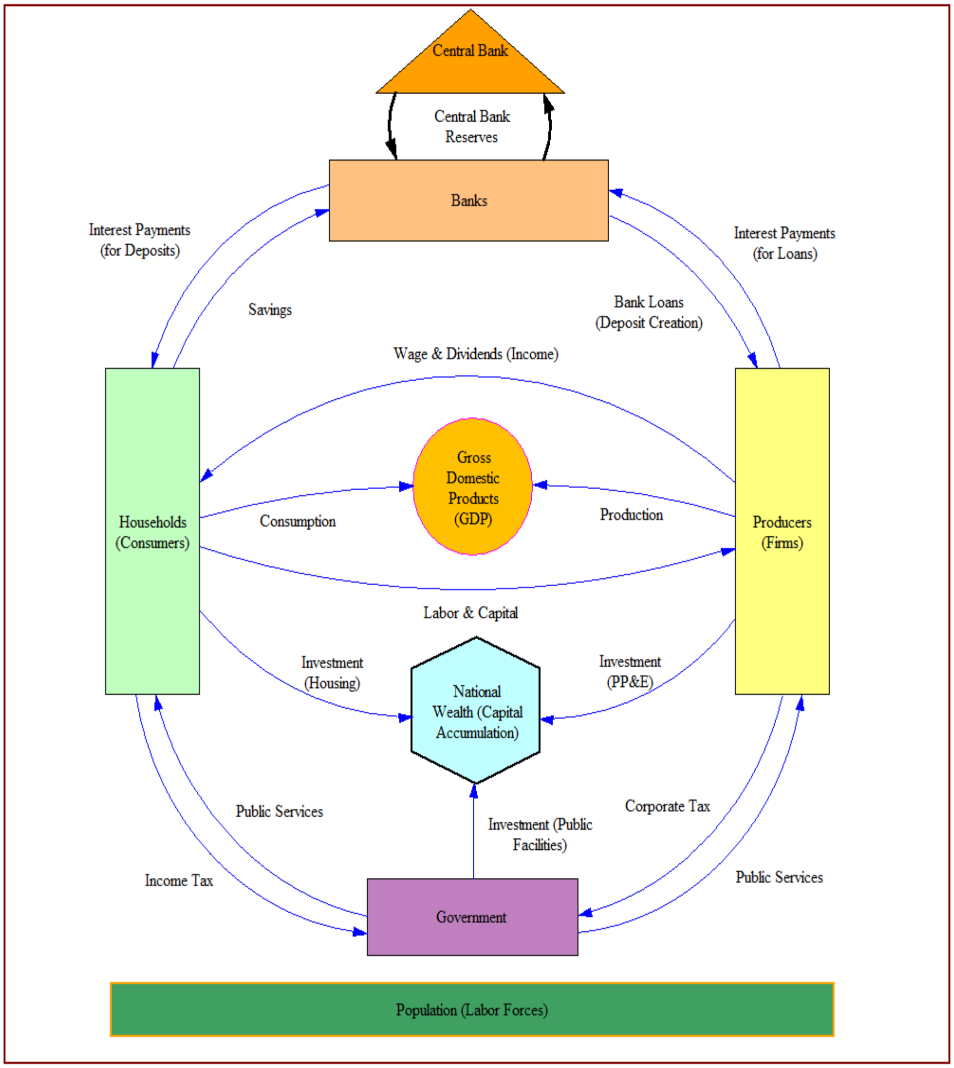


Figure 3: Overview of Macroeconomic Model

in the current model based on stock approach modeling of banks where money stock, consisting of currency and bank deposits, are created endogenously by bank loans. They are then used for inter-sectoral transactions, illustrating flows of money around the economy. Specific transactions are explained in more detail in Section 2.5 below. As shown by a dark green box at the bottom of Figure 3, the model integrates structure of population cohorts, thus incorporating demographic changes that affects labor market dynamics.

2.1.2 Extended Structures & Assumptions

The base model by Yamaguchi [44, 2013] adopts the flow approach modeling of bank lending transactions.[4] Accordingly, there are two major changes made in our stock approach model as listed below:

1. Deposit Creation Theory
2. Monetary Policy Transmission Channel via Money Market Rate

Regarding item 1 in the above list, the base model is revised to reflect deposit creation theory by applying the stock approach modeling of bank lending transactions. To accommodate this, the model newly introduces government's deposit account at the on liability side of the central bank's balance sheets, which is shown by a green box in Figure 5 below. Accordingly, all transactions involving the government & non-government sectors (such as household & producers) are made by transfer of bank deposits, which are simultaneously settled by transfer of reserves between accounts at the central bank. Commercial bank's account at the central bank is shown by a purple box on the liability side of the central bank balance sheets in Figure 5. This has allowed the model to incorporate system structure of central clearing mechanism such as the Real Time Gross Settlement (RTGS) system operated by Bank of Japan. This has also increased traceability of base money (M_0) such as in tax payments, government expenditures and interest payment on government bonds in the model.

In order to incorporate monetary policy transmission channel, interest rate is now determined by supply-demand relationship of central bank reserves, which are in turn affected by a number of factors inside the model. This alternative determination process represents dynamics of money market rate where central bank can directly affect supply of reserves through market operations.

These extensions are discussed in more detail in the following sections.

2.2 Determination of Bank Lending

Different Constraints on Loanable Funds

Accounting mechanics behind the deposit creation theory imply dissimilar constraint on the amount of loanable funds from that of intermediation theory. Under the flow approach modeling, banks face with constraint on liquidity by the amount of cash or reserves at hands. In other words, should the demand for loans exceeds the loanable funds, theory implies banks can only lend out up to the extent which they have acquired from depositors. Therefore, a stylized

[4] In terminology used by Yamaguchi & Yamaguchi [45, 2016], the *flow* approach modeling reflects intermediation theory of banking, whereas the *stock* approach incorporates deposit creation theory. The term 'flow' is used descriptively to emphasize constant circulation of depositors money caused by banks lending activity as the intermediation theory implies. Note that this differs from 'flow' variables (or rates) used in system dynamics modeling terminology. Contrary to the intermediation theory, deposit creation theory implies direct changes of bank deposits, which is a 'stock' variable in system dynamics model or levels.

condition for bank lending under the *flow approach* modeling is expressed as below[5]:

$$\text{Bank Lending}_{Flow} = MIN(\text{Desired Borrowing, Cash}_{Banks})$$

where *Desired Borrowing* represents total demand for bank by producers sector. On the other hand, bank lending increase loans receivable (asset) with the corresponding increase of demand deposits (liability) under the stock approach modeling. Hence, a condition for bank lending under the *stock approach* modeling is determined as follows:

$$\text{Bank Lending}_{Stock} = MIN(\text{Desired Borrowing, MLF})$$

where MLF stands for maximum loanable funds. Specifically, bank lending to producers is called *Corporate Lending* in the model, which in turn depends on various factors explained in section 2.4.

$$\text{Corporate Lending} = MIN(\text{Desired Borrowing, MLF}) \quad (1)$$

Our stock approach model applies this type of condition on the supply-side of bank lending.

Maximum Loanable Funds

Maximum Loanable Funds (MLF) is determined as follows:

$$\text{MLF} = \frac{\frac{R_{Banks}}{\epsilon} - (D_d + D_s)}{\text{Lending Delay Time}} \quad (2)$$

where ϵ denotes required reserve ratio, D_d is the sum of demand deposits held by producers and households, D_s is savings deposits held only by households.

2.3 Interest Rate Determination

Dynamics of Money Market Rate

Central banks of the major economies such as in the United States, Canada, Australia have adopted overnight interbank lending rate as their policy rates. In Japan, policy rate has been changed to a short-term overnight interbank lending rate since 1995, which is conventionally referred as *call rate* [29, 2011]. Under fractional reserve banking system, banks are facing with demand for reserves to meet the legal reserve requirement. While actual implementation of reserve requirement policy differ among jurisdictions, there are mainly three factors that affect bank's demand for reserves during normal times: 1. deposit transfers instructed by customers (transaction demand), 2. reserve requirement demand, and 3. demand for withdrawal in cash by customers.

[5] To be more precise, the concept of delay time needs to be introduced in the model equation so the above condition should be $MIN(\text{Desired Borrowing, Cash}_{Banks}/\text{Lending Delay Time})$, which keeps unit consistency.

In our macroeconomic model, banks are aggregated into a single economic sector. Hence, call rate i_R conceptually represents average nominal interest rate for wholesale funding determined by demand and supply relationships as follows:

$$\frac{di_R}{dt} = \psi(R^* - R^s) \tag{3}$$

where R^* denotes demand for reserves, while R^s denotes total supply of reserves. Let us define nominal call rate specifically as follows:

$$\frac{di_R}{dt} = \frac{i_R^* - i_R}{\text{Adjustment Time}} \tag{4}$$

where i_R^* is a desired call rate (nominal). Desired call rate is in turn determined by

$$i_R^* = i_R \cdot \frac{1}{\left(\frac{R_{Banks}}{RR}\right)^e} \tag{5}$$

where e is an elasticity of call rate. Hence, equation (4) describes an adjustment process of the current call rate i_R towards the desired rate, which is in turn determined by the supply demand ratio of central bank reserves. Supply-demand relationship of reserves is called *Reserves Tightness*, which is expressed by a ratio defined as follows:

$$\text{Reserves Tightness} = \frac{\text{Reserves}_{Banks}}{\text{Required Reserves}} = \frac{R_{Banks}}{RR} \tag{6}$$

where R_{Banks} is the total supply of reserves held by the banking sector as a whole. Total reserves supply is represented by reserves account shown by a purple colored box on the liability side of central bank balance sheet in Figure 5.

Required Reserves, on the other hand, is determined by

$$\text{Required Reserves} = \epsilon \cdot \text{Deposits}_{Banks} \tag{7}$$

where ϵ is a required reserve ratio, which is assumed to be a constant value of 0.02 or 2% under base run simulation. In this way, desired call rate i_R^* is determined according to how much central bank reserves are available for the whole banking sector relative to the required amount of reserves set by ϵ .

Transmission Channel via Money Market Rate

A set of policy instruments and specific targets change over time, and they differ among different central banks. Monetary policy transmission mechanism describes cascading processes through which real, monetary, and psychological variables change in response to changes in policy target. The mechanism relies on multiple channels, which are based on assumptions about causality between economic variables.

The interest rate determination based on supply-demand of reserves functions as a starting point of monetary policy transmission channel, which can be controlled through market operations by central bank in the model. In the current version, effect of policy-induced changes are assumed to transmit mainly via changes in prime lending rate applied to bank loans of producers (interest rate channel)

2.4 Demand for Bank Loans & Debt Repayment

It is explained that bank lending to producers are determined by the condition specified in equation (1). How do producers decide, then, how much they need to borrow from banks? What is the desired amount of borrowing?

Desired Borrowing of Producers

Producer's demand for loans, called *Desired Borrowing*, are determined according to a direct financing ratio defined as follows:

$$\text{Desired Borrowing} = \text{Desired Financing} \cdot (1 - \text{Direct Financing Ratio}) \quad (8)$$

Direct financing ratio is treated as an exogenous constant in the current model, and assumed to be 0 under the current parameter settings; that is, producers do not issue additional capital shares and rely on loans from banks.

Liquidity Deficit of Producers

To derive producer's demand for liquidity (desired financing in equation (8)), our stock approach model follows the concept of cash-flow management, which was originally incorporated in the base model. However, we apply the term Net Deposit Flow (NDF) to account for difference between cash and deposits as it becomes inconsistent to continue to use the term "cash" under our stock approach model where almost all transactions are settled by transfer of deposits.

NDF of producers are divided into three factors based on the nature of corporate activities:

1. Net Deposit Flow from Operating Activities
2. Net Deposit Flow from Investing Activities
3. Net Deposit Flow from Financing Activities

Complete logical steps are illustrated at the bottom left corner of producer's balance sheet shown in Figure 16 in the appendix section.[6] From these three factors, liquidity deficit of producers is obtained as follows:

[6] In this paper, we omit details of all three factors that add up to producer's liquidity deficit due to limited pages for conference submission guidelines.

$$\text{Liquidity Deficit} = \text{NDF}_{operating} + \text{NDF}_{investing} - (\text{Expenditures}_{DebtFinance} + \text{Expenditures}_{EquityFinance}) \quad (9)$$

Note that newly acquired funds from borrowings and issuance of capital shares must be deducted. From the above equation, it follows that liquidity deficit defined above becomes negative value in the case of liquidity deficit. Hence, it is converted to a positive value with the following condition:

$$\text{Desired Financing} = MAX(-\text{Liquidity Deficit}, 0) \quad (10)$$

Repayment of Bank Loans

Producers are assumed to repay bank loans on average within a fixed period of time called Debt $\text{Period}_{Producers}$. Specifically, amount of debt repayment is defined as follows:

$$\text{Debt Repayment}_{Producers} = \frac{\text{Bank Loans}_{Producers}}{\text{Debt Period}_{Producers}} \quad (11)$$

where debt period is treated as an exogenous parameter in the current model, which stays constant throughout the simulation. The above formulation means that rate of debt repayments increase as loans increase. Furthermore, repayment of bank loans directly affects money stock under the stock approach modeling.

2.5 Transactions among Five Sectors

We now describe some of the transactions among producers, consumers, government, banks and central bank considered in our macroeconomic model.

Producers

Major transactions of producers are summarized as follows as illustrated in Figure 16.

- Producers maximize their profits while making capital investments to generate output called GDP (revenues), which are first recorded as inventories on its balance sheet.
- Aggregate demand in the economy becomes the sales of producers sector. Thus, it becomes their sales revenue which depletes their inventories. Producers receive payments in deposits.
- Producers pay excise tax (tax on production), deduct the amount of depreciation, pay wages to workers (households) and interests on their bank loans out of the sales revenues. The remaining becomes profits before tax.

- They pay corporate taxes to the government out of the profits before tax according to a corporate tax rate.
- The remaining profit after taxes is paid to shareholders (households) as dividends based on dividends ratio.
- Producers are thus in a state of liquidity deficits. To continue making desired investment, therefore, they ask for loans from banks on which they pay accrued interests (indirect financing) or choose to issue capital shares (direct financing).

Households

Transactions of households are summarized below and illustrated in Figure 17.

- Households receive wages and dividends from other sectors as part of their total income.
- Financial assets of households consist of demand and time (or savings) deposits, government bonds, against which they receive interests income from banks and the government. (No additional capital shares are assumed to be held by households in the current model).
- In addition to the above mentioned income, households receive deposits whenever the government bonds are redeemed.
- Out of these income as a whole, households are obliged to pay income taxes. The remaining income thus becomes their disposable income.
- Out of the disposable income, they spend on consumption that is determined by their marginal propensity to consume.
- The remaining amount after all the above transactions are either kept as demand deposits, or spent on investment in government bonds, or saved as time deposits which have higher rate of interest rate.

Government

Transactions of the government are summarized as follows and illustrated in Figure 18.

- Government collect various taxes such as income taxes from households, corporate taxes from producers as well as excise tax on production.
- Total government spending consists of government expenditures, debt redemption to each sector and interests accrued on its debt.
- Government expenditures are assumed to be endogenously determined by either the growth-dependent expenditures or (tax) revenue-dependent expenditures.

- If spending exceeds tax revenues, government has to borrow money from banks and households by newly issuing government bonds.

Banks

Transactions of banks are illustrated in Figure 4, some of which are summarized below.

- Banks meet demand for cash by households sector. Banks accept to open deposits account for households and producers. In the current model, banks are assumed to pay interest on deposits to households only.
- They are required to maintain reserves at the central bank according to a required reserve ratio (*fractional banking system*).
- From their own funds, banks invest in newly issued government bonds (primary dealers market), against which interests are paid by the government through government deposits held at the central bank.
- Loans are now made to producers by deposit (or credit) creation, and banks receive interests on which a prime lending rate is applied.
- Their retained earnings thus consists of interest revenues from producers and government less interest payment to households. Wages are paid to workers (households).
- Deposits created by banks function as the primary means of payment in transactions. Hence, All transactions between household and producers go through banks and processed by them.
- Payments that involve non-bank private sectors (producers, households) and the Government, such as tax payments, are ultimately done through the deposit account of banks and the government both held at the central bank.

Central Bank

Central bank plays a crucial role of providing reserves. Source of assets against which base money is issued is constrained to government bonds. In short, base money is issued primarily against debts of the government in the current model. Thus, central bank directly affects the amount of reserves through market operations. Specifically, this is done through adjustment of required reserve ratio, size and timing of market operations as well as direct lending facility to banks.

Transactions of the central bank are summarized below as illustrated in Figure 5.

- Central bank conducts market operations by purchasing or selling government bonds to banks, thereby affecting the supply-demand of money market dynamics and determination of nominal call rate.

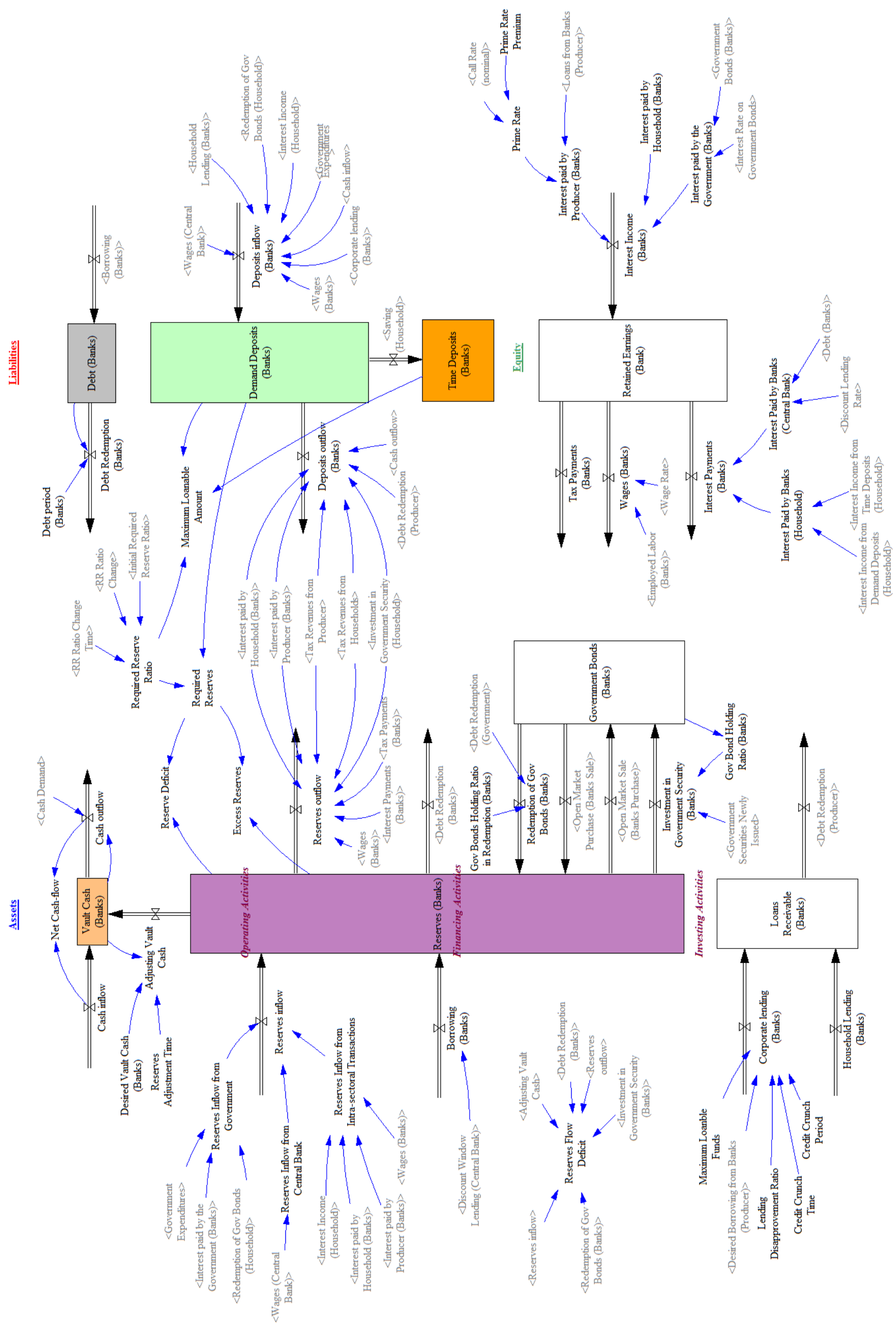


Figure 4: Balance sheet of Banks & Transactions

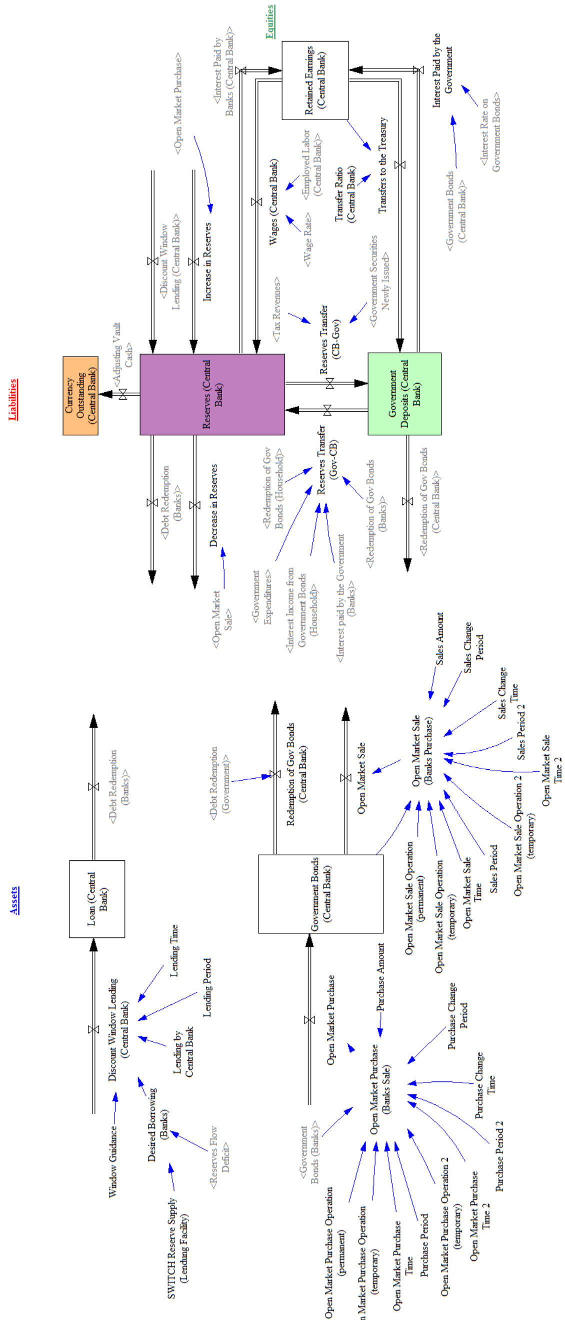


Figure 5: Balance sheet of Central Bank & Transactions

- Moreover, the centra bank can inject reserves exogenously by extending loans to banks when needed (lending facility).
- Banks are required to hold a certain amount of deposits at the central bank. By controlling this required reserve ratio, central bank can also control supply-demand relationships of reserves.

Accordingly, the central bank in our model does not and cannot control money supply directly but influences it through different policy instruments such as market operations, reserve ratio and loans to banks.

2.6 Causal Loop Diagram

Figure 6 provides summary of causality among variables and feedback loops identified in the model. Arrows denote causal influences through its direction. Blue arrows indicate a positive causal relationship while red indicates opposite relationships.[7] Arrows with double line dash crossing them indicate a significant time delay presumed in causal influence. The model is composed of reinforcing (R) and balancing (B) feedback loops. Determination of call rate discussed in section 2.3 is reflected at the bottom left corner of Figure 6.

Double crossings on causal arrows indicates that there is a significant time delay assumed between model variables. Specifically, our model assumes the following time delays which are incorporated as exogenous constants.

- Delays in Aggregate Demand Forecasting
- Delays in Perception of Capital Demand
- Delays in Capital Construction

3 Base Run Simulation & Behavior Analysis

A macroeconomic model under the stock approach is completed. We are now in a position to explore its behavior. Population data from Japan is referenced for the calibration of parameters around population cohort model shown in Figure 19 in the appendix. All other parameters of the model are chosen arbitrarily except the initial level of potential GDP. Therefore, current simulation should be considered as exploratory mode of study. For a unit of currency, Yen is chosen. Time boundary is set from 1980 to 2050.

[7] For instance, if there is a blue arrow from variable X to Y, it is interpreted as follows: If X increases, then Y also increases above what it would have been otherwise if all else were equal. Chapter 5 of Sterman [36, 2000] provides detailed explanations and discussion on the proper usage of CLD.

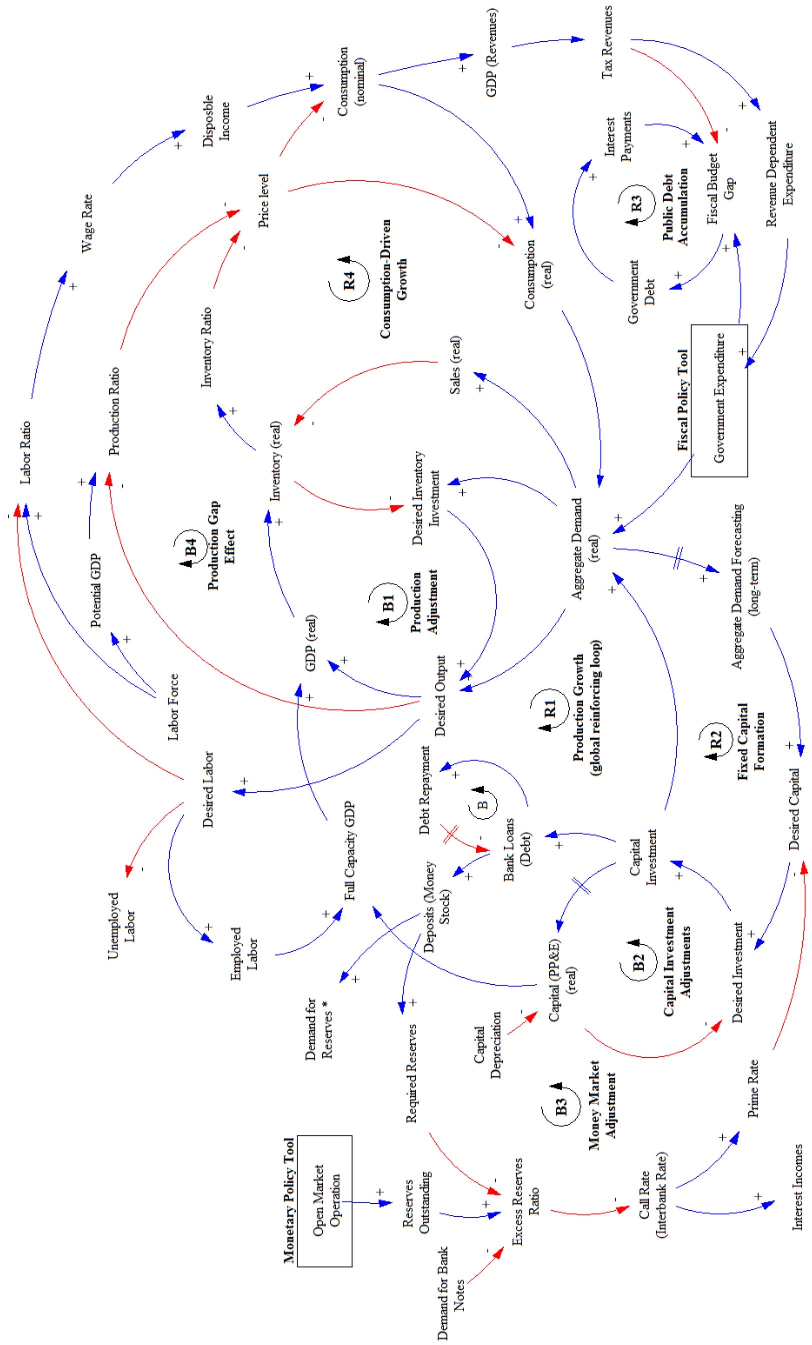


Figure 6: Determination of Key Macroeconomic Variables

3.1 Base Run Simulation

Growth, Stagnation and Mild Recovery

Let us first overview behavior of gross domestic product of the model economy. Initial Potential GDP is set at 300 trillion yen/year. Figure 7 shows behaviors of Nominal GDP (blue), real GDP (red), Aggregate Demand (green), Full Capacity GDP (grey) and Potential GDP (black). Potential GDP (black) disappears soon after year 1984 behind the Full Capacity GDP shown in a grey line. This is because demand for labor exceeds the supply during high economic growth period. The reason why nominal GDP exceeds potential GDP during a period between 1986 - 2005 is due to high inflation rate generated by demand-pull force, which is confirmed by higher inflation rate during the same period captured in Figure 10 below. After periods of high growth in the early phase of the simulation, gradual decline in economic activity is observed. Then the economy stagnates from around year 2000 as depicted by the behavior of nominal GDP (blue). After nearly 10 years of stagnation, nominal GDP finally begins to show a mild upward trend around year 2015. Subsequently, the potential GDP (black) reaches its peak level at year 2041, and records negative growth rate afterwards. Let us next analyze this long-term behavior of growth, stagnation, and mild recovery observed in our base run simulation with a focus on underlying dynamics in each phases in detail.

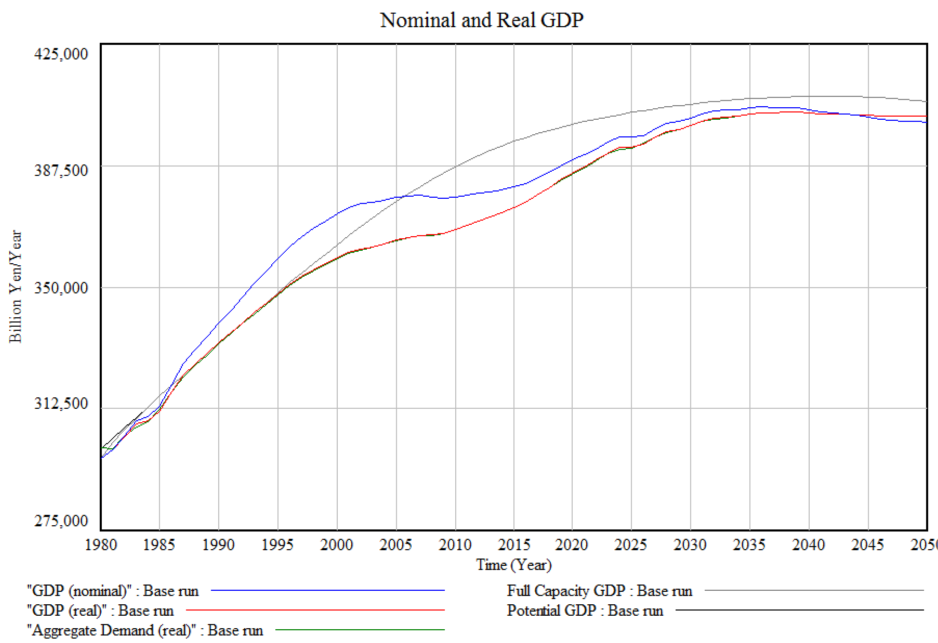


Figure 7: Behaviors of Real and Nominal GDP

The next Figure 8 depicts higher growth rates in both real and nominal GDP during early phase of the simulation, reaching approximately 2% at its peak in year 1986. The growth during this period is largely led by the growth of consumption spending by households as shown by a red line in the same Figure 8. This consumption-led growth initially increases the real GDP (blue), which then stimulates the long-term forecasts on aggregate demand by the producers, thereby increasing capital investment (green) continuously until the year 1998. These underlying dynamics indeed confirms that Consumption-Driven Growth (R4) and Production Growth Loop (R1) illustrated in the CLD (Figure 6) are dominant during early phase of the simulation. However, after the higher growth phase observed by the end of 1988, growth rates of both real and nominal GDP begin to diminish. At a year 2008 and 2009, growth rate of Nominal GDP records negative value of - 0.2 and - 0.1% respectively. After years of low growth in aggregate demand, and deflationary trend caused by supply push-down force, the economic output gradually begins to recover. This self-propelling recovery from recession observed in base run case is driven largely by the recovery in consumption expenditures as depicted by a red line in figure 8, which is caused by the effects of price-level on consumption.

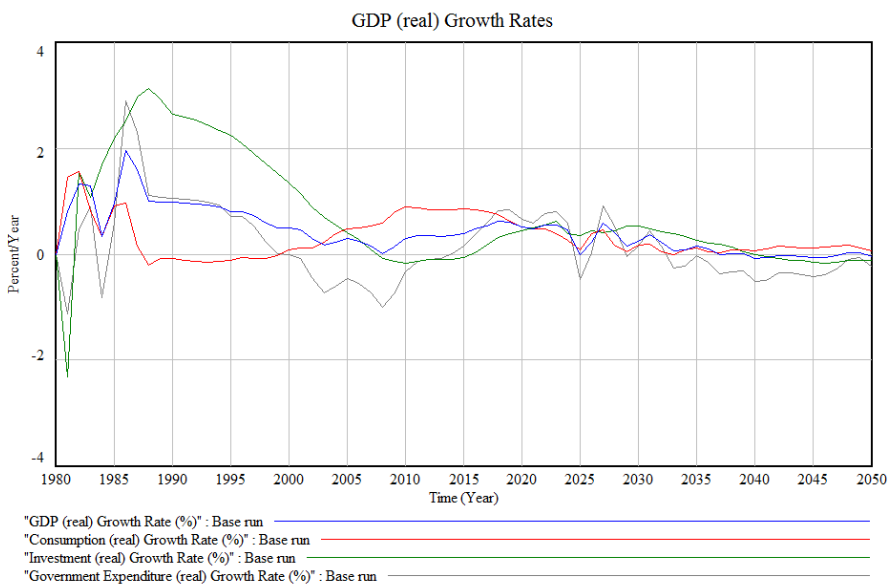


Figure 8: Growth Rates of Real GDP & Aggregate Demand (real)

Decline of Productive Population

Labor force plays significant role in our model in that it affects economic outputs in the long-run, which is incorporated in the Cobb Douglas production function. The long-term trend of diminishing growth in GDP is largely caused by diminishing returns to scale assumed in the production function; that is, $\alpha+\beta < 1$, as well as decrease in the labor force. Demographic change produced in the base run simulation is depicted in Figure 9. Population cohorts are divided into three cohorts among age 0-14 (blue), 15-64 (green) and above 65 (black) respectively. The same figure also show historical data from Japan between 1980 - 2013 obtained from population census, which are shown by red (age 0-14), grey (age 15-64) and brown (above 65) lines respectively.[8] Figure 19 in the appendix illustrates stock-flow diagram of population cohorts.

While the objective of the current research is not to predict economic growth paths in the real world, we have assumed historical demographic changes of Japan to prevent our analysis from being purely theoretical. Specifically, the model takes its initial values of population cohorts from Japan data. Then, parameters around the population model were calibrated to fit with the reference mode. Figure 9 thus compares demographic changes in Japan (legend name: Reference mode) and the base run simulation. It is observed that the productive population have reached its peak level around the year 1995 and have started to decline since.

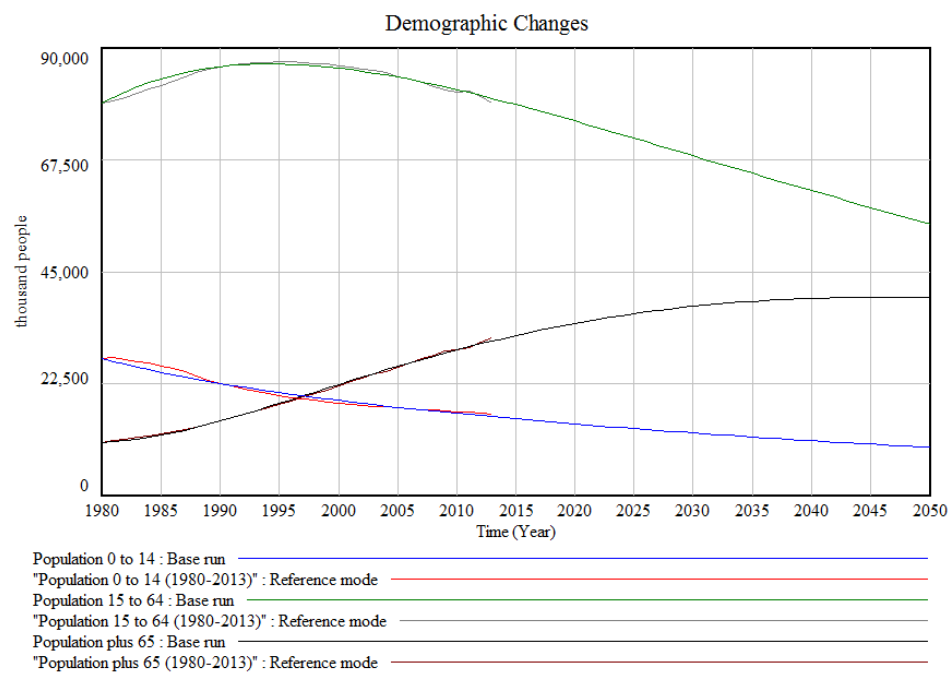


Figure 9: Demographic Data (Japan) & Base Run Simulation

[8] Data source was obtained from Statistics Bureau of Japan in Ministry of Internal Affairs and Communications: http://www.stat.go.jp/english/index.html

Inflation and Deflation

Demand pull-up or supply push-down force affects the price level in the model. As we observed earlier, the economy experiences high growth supported by consumption-led demand during its early phase. This generates demand-pull forces on price level during the period between 1980 until the end of 2002 depicted by a blue line in Figure 10 below.

Driven by Production Adjustment Loop (B1) economy's desired output gradually begins to grow at a diminishing rate with combined effects of inflation on aggregate demand. This leads to a peak in growth rate of capital investment at 1988 as shown by a green line in Figure 8. From year 1988 onwards, the growth rate of real capital investment begins to decrease and the overall economy begins to be sluggish. The growth led by the production growth loop (R1) starts to get dampened, and balancing loops of production adjustment (B1) and capital investment adjustment (B2) begin to dominate. An enduring dominance of these balancing feedback loops finally drive the economy into deflation from year 2003 as depicted by a blue line in Figure 10. As the economy gains momentum led by an mild recovery in consumption spending from around year 2006 due to the effect of price level on Household's consumption behavior. This consumption-led recovery discussed above is shown by a red line in Figure 8.

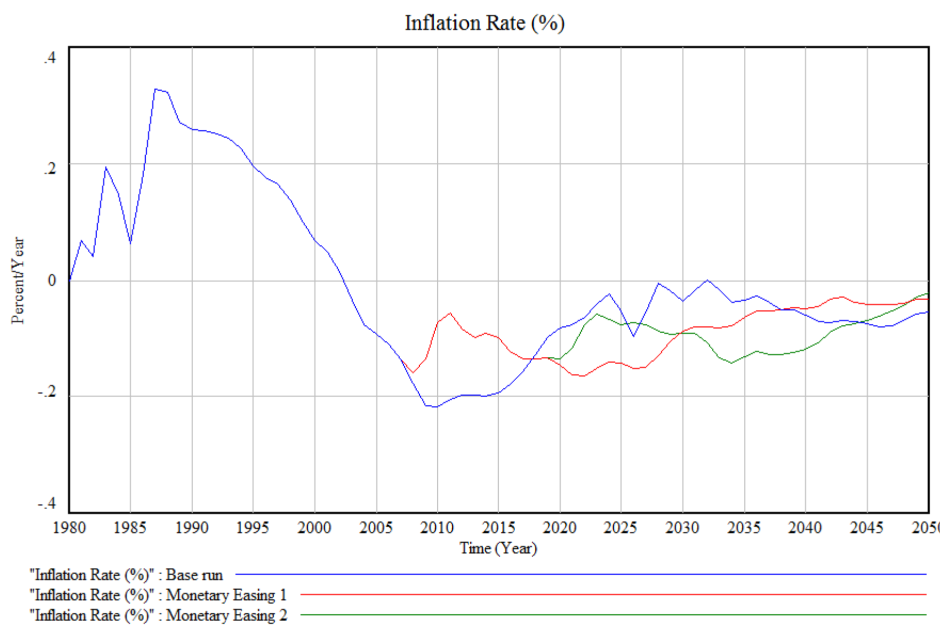


Figure 10: Behavior of Inflation Rate

Expansion of Monetary Aggregates

The model captures behaviors of currency outstanding, base money (M_0), M_1 and M_2 under the fractional reserve banking system. The difference between M_1 and M_2 as defined in the current model is whether time deposits of households sector are included as a component of money stock. M_1 consists of currency outstanding and demand deposits while M_2 includes time deposits in addition to the components of M_1. Figure 11 reports behaviors of the three primary indicators, M_0 (blue), M_1 (red) and M_2 (green) as well as other monetary aggregates such as reserves (grey), demand deposits of households (dark grey) and producers (brown). Compared to other indicators, M_0 remains fairly stable at a lower level while money stock grows rapidly as the economy grows. Prior to the introduction of quantitative easing policy, the similar behavioral pattern of monetary aggregates has been observed in real economies such as in Japan show in Figure 2. It turns out that our stock approach model is able to capture the monetary phenomenon based on the flow of funds account framework.

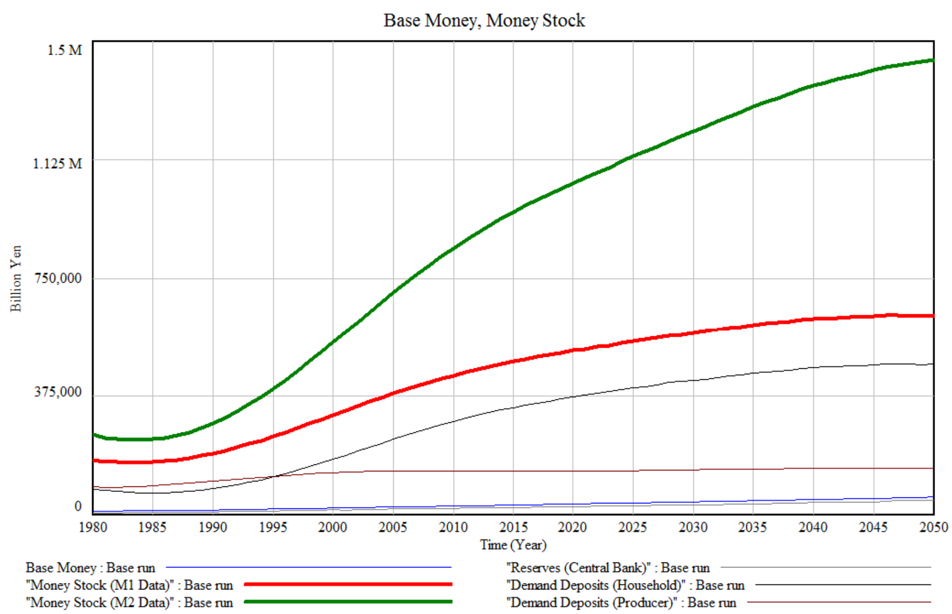


Figure 11: Behaviors of M_0, M_1 & M_2

4 Exploratory Simulation Experiments

Let us next explore a scenario case where central bank implements monetary easing policy and how the model economy responds to policy-induced changes.

4.1 Monetary Easing Policy: Asset Purchase Operation

In base run case above, the model assumes a constant required reserve ratio at 2% for the whole period. Under the growing economy, such as in the base run case, demand for money stock continued to increase in the economy as a whole. Continuous increase in demand for money stock under no additional supply of M_0 would create an upward pressure on call rate (money market rate). To keep the interest rate from increasing, it is also assumed in the base run case that central bank constantly purchases a fraction of government bonds held by banks, thereby injecting reserves into the banking system as shown by a blue line in Figure 13. Due to this policy stance on the central bank assumed in the base run case, call rate continue to decrease so as to continuously stimulate capital investment. The continuous decline of call rate is shown by a blue line in Figure 12.

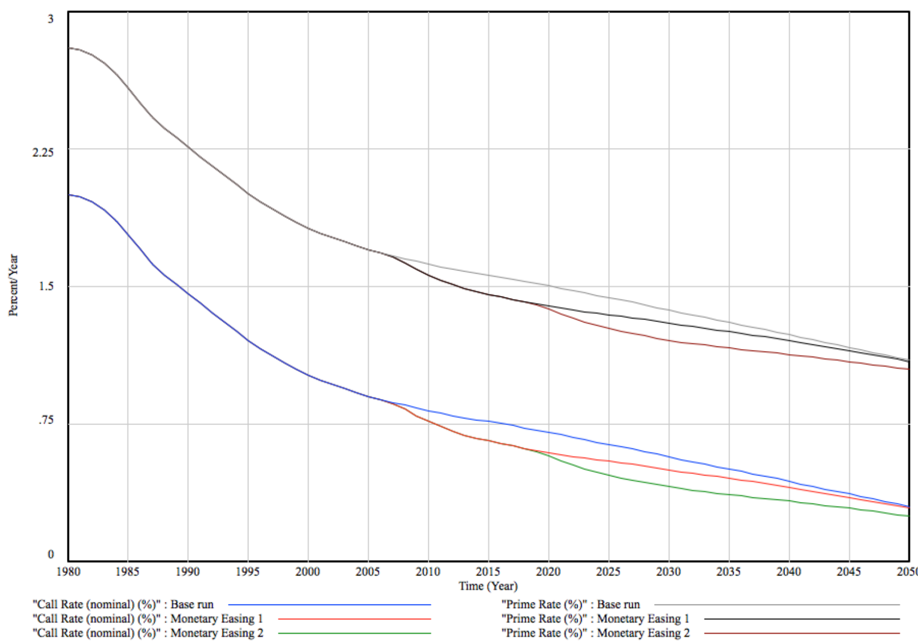


Figure 12: Behaviors of Call & Prime Lending Rate

However, as we saw in the previous section, the economy experienced stagnation despite this easing policy. This economic downturn is depicted by a blue line in Figure 14, showing a widening GDP gap starting from the second half of 1990's. Let us assume that central bank, observing this trend, and using her own model of monetary transmission mechanism, now decides to stimulate economy or (capital) investment by implementing monetary easing policy. Specifically, we assume that central bank implements purchase operation starting from 2006 for 2 years by increasing the yearly purchase amount of government bonds by

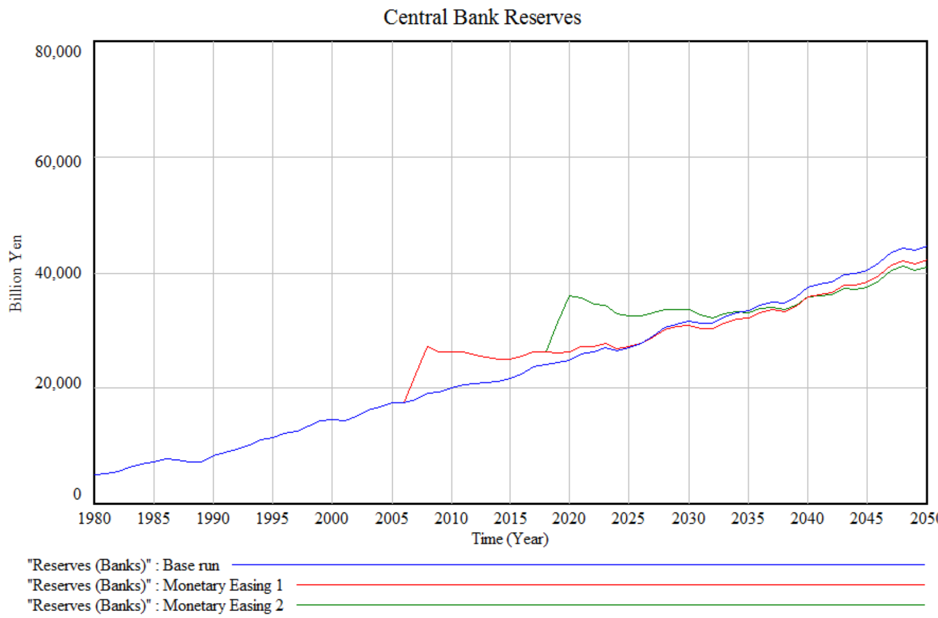


Figure 13: Injection of Reserves at t=2006 and 2018

1.5% held by the banking sector. As a result of the policy change, supply of reserves temporarily increases compared to the base run case shown in blue line. This scenario is labeled as Monetary Easing 1 in the graph legend and illustrated by a red line in Figure 13.

Temporary Reduction of GDP gap

Figure 12 illustrates changes in call rate and prime lending rate realized by monetary easing policy. All interest rates are assumed to move in lockstep with call rate. Consequently, a change in call rate induced by the easing policy is directly reflected to prime lending rate as illustrated in CLD in Figure 6. This monetary easing policy turns out to be effective in alleviating the GDP gap between years 2006-2017 during which the economy has sufferes most from the recession in the base run case.

Furthermore, let us examine a case where the central bank implements another monetary stimulus by introducing another series of market purchase operation starting from 2018 for 2 years. More specifically, central bank now increases the amount of government bond purchases by 2% from 2018. This scenario is named Monetary Easing 2 and shown by a green line in the same Figures 13, 14. As a result of the second series of monetary easing (Monetary Easing 2), both call and prime rates are further lowered as shown by green and red lines respectively in Figure 12. This decrease in interest rates seems to stim-

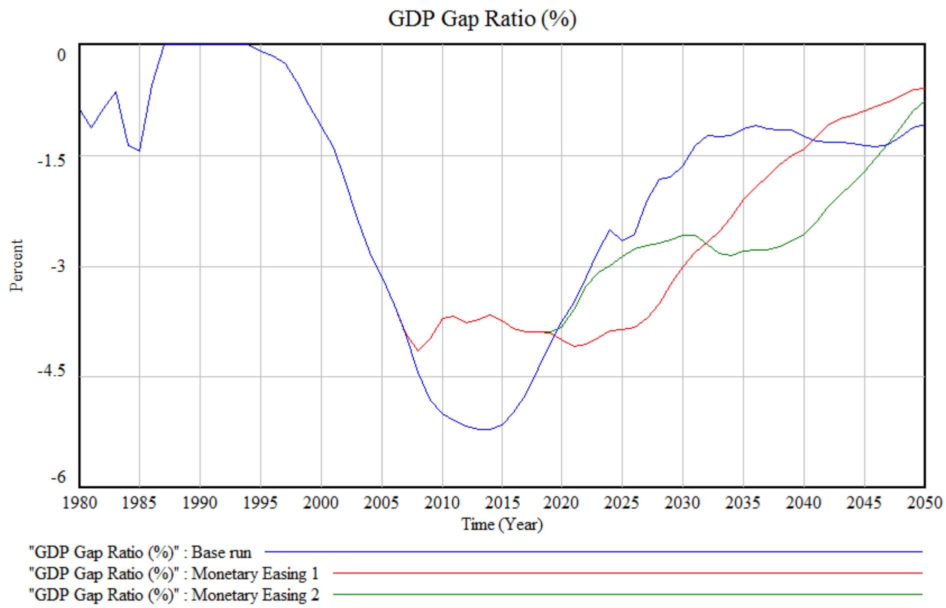


Figure 14: Monetary Easing reduces GDP gap temporarily

ulate capital investments effectively, resulting in a further reduction of GDP gap from 2018 compared to the case in monetary easing 1 (red line) as shown in the Figure 14. Once monetary easing is dropped at year 2008 and 2020 respectively, results from both simulation cases show the economy keeps its pace, and finally start to recover gradually, driven largely by consumption-driven growth loop (R4) as similarly analyzed in base run case.

Temporary Reduction in Deflation Rate

Let us now take a look at this case from a different perspective. Figure 10 shows the effect of monetary easing policy on price level. The first series of monetary easing policy shown by a red line shows that deflationary pressure on economy is somewhat counteracted by the policy stimulus. However, once the policy is pulled up after 2 years, the economy is thrown back into deflationary path again. A green line in the same Figure 10 shows temporary improvements in inflation rate kindled by the second series of monetary easing. However, the effects of easing policy on inflation rate is, again, shown to be limited after 2 years when the policy is dropped. Simulation experiments in these two cases seem to imply limitations of monetary easing policy in fully counteracting deflationary trend when the economy is experiencing stagnation precipitated by the low level of aggregate demand and decline in productive population.

4.2 Growth Paths of Real GDP

In addition to the case of monetary policy, we explored different scenario cases mainly by changing parameter values. Figure 15 shows different growth paths of real GDP under different scenarios such as base run (blue), elastic price (red), monetary easing 2 (green), monetary tightening 2 (grey), credit crunch (black), and currency ratio (brown) cases. The model turns out to be capable of producing diverse behaviors caused by gradual and sudden changes in macroeconomic conditions transpired through different channels of feedback effects incorporated into the current model under stock approach modeling.

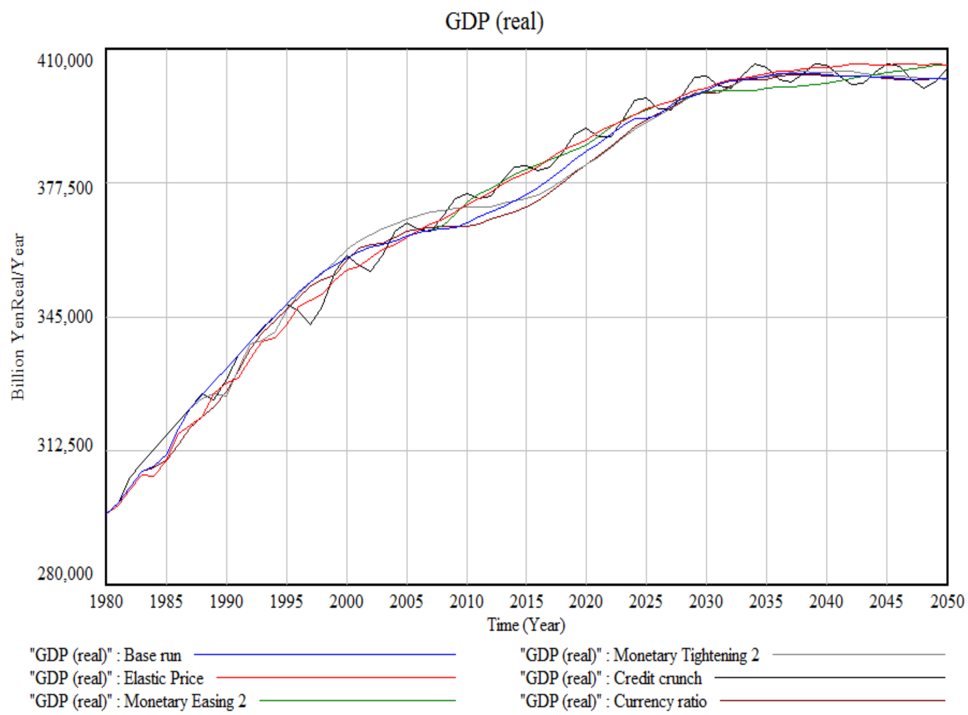


Figure 15: Growth Paths of GDP

5 Discussions & Conclusion

5.1 Model Assumptions & Limitations

Wishful Thinking in Interest Rate Channel

A brief remark on assumptions made in our model is relevant here to understand the temporary effectiveness of monetary easing policy observed in our simulation experiments. The reason why the easing policy becomes effective in stimulating economy is due to particular assumptions presumed in the transmission channel of monetary policy. As illustrated at the bottom left corner in the causal loop diagram, there is a negative cause and effect relationship between desired capital investment of producers and prime lending rate on bank loans. Since demand for capital investment is assumed to be sensitive enough to a change in the prime lending rate, reductions in call rate causes a reduction in prime lending rate. Consequently, the policy-induced changes directly and immediately affected the desired level of capital investment. However, there is no guarantee that this relationship always holds in reality. In fact, this could become a wishful thinking in the face of balance sheet problem as experienced in the United States Economy during the Great Depressions [13, 1933], and recently evidenced by the largely ineffective monetary policy in Japan since the burst of asset bubble in the 1990's [22, 2009]. This is one of wishful thinkings present in our stock approach model, and considered to be one of limitations for its application into policy analysis. Accordingly, the use of current model may be limited to exploratory mode of research and purposes.

5.2 Directions for Model Extension

Simulation experiments discussed above are exploratory in nature, and the focus has been on the dynamics within a closed economy. While current version of the model could provide further insights as a learning tool, it should also provide analysis on historical time-series data to be used as a decision-supporting tool. Towards such research objectives, we list some of the potential directions for model extension as follows.

1. Incorporate overseas sector
2. Relax profit maximization rule of producers investment decision
3. Incorporate granular descriptions of money market dynamics

Depending on specific economy under study, considering feedbacks from foreign exchange dynamics is crucial for understanding increasingly imminent issues such as domestic inflation caused by foreign exchange shock, and international spillovers.

Japanese companies have spent nearly two decades repairing their balance sheets damaged by the burst of asset price bubble in the early 90's[22, 2009]. Regarding item 2, the conventional assumption in production function may not always hold true in real world economy. Relaxing the profit maximization rule in the current model may allow us to understand massive reduction of bank loans observed in Japan.

Regarding the item 3, a legally required reserve ratio plays a crucial role which imposes behavioral rule on money market participants. At institutional level, demand and supply of reserves are affected by both internal and external factors (asset-liability management). The current model abstracts heterogeneity of market participants and limits the scope of analysis on policy transmission process via short-term inter-bank funding rate. In reality, effects of monetary policy may be entrained, reinforced or neutralized within interbank money market without permeating through larger parts of the economy. Thus incorporating more granular analysis of interbank market may increase explanatory power of the model using agent-based modeling.

5.3 Conclusion

A macroeconomic model consisting of five domestic sectors is developed based on the stock approach where new deposits are created through loans by the commercial banking sector. The model then introduces interest determination process based on supply-demand relationship of central bank reserves, representing interest rate channel of monetary transmission mechanism. These structural extensions from the base model allows more realistic approach in studying credit creation and exploring how asset purchase operation by central bank might affect macroeconomic variables such as GDP, and price level. To demonstrate such ability, base run simulation was analyzed. Then, we conducted exploratory scenario experiments where monetary easing policy is shown to be effective in alleviating GDP gap temporarily under specific assumptions in policy transmission channel. The model is also shown to produce diverse macroeconomic behaviors caused by different stabilization policy, which are amplified by reinforcing and balancing feedback loops. Limitations of the current model is also discussed. By further adjusting structural and behavioral assumptions, we believe the generic model could provide a useful tool for historical analysis with time-series data of specific national economy.

References

[1] Kenneth J. Arrow and Gerard Debreu. Existence of an equilibrium for a competitive economy. *Econometrica, 22(3): 265-290*, 1954.

[2] Benjamin S. Bernanke. *Essays on the Great Depression.* Princeton, New Jersey:Princeton University Press, 2000.

[3] Benjamin S. Bernanke. Some thoughts on monetary policy in japan. remarks before the japan society of monetary economics, tokyo, japan. may 31, 2003. https://www.federalreserve.gov/boarddocs/speeches/2003/20030531/default.htm, May 31, 2003.

[4] Benjamin S. Bernanke and Vincent R. Reinhart. Conducting monetary policy at very low short-term interest rates (policies to deal with deflation). *American Economic Review*, May 2004.

[5] Olivier Blanchard. *The State of Macro.* National Bureau of Economics Research, nber working paper series no.14259 edition, August 2008.

[6] Olivier Blanchard and Dell'Ariccia. Rethinking macroeconomic policy. *Journal of Money, Credit and Banking, 42: 199-215*, 2010.

[7] Olivier Blanchard and John Simon. The long and large decline in u.s. output volatility. *Brookings Paper on Economic Activity*, 1:135–164, 2001.

[8] Barry Eichengreen. Viewpoint: Understanding the great depression. *Canadian Journal of Economics, 37(1): 1-27*, 2004.

[9] Barry Eichengreen and Jeffrey Sachs. Exchange rates and economic recovery in the 1930's. *Journal of Economic History, 45(4): 925-46*, 1985.

[10] Silvano Cincotti Hlynur Stefansson Jon Thor Sturluson Einar Jon Erlingsson, Andrea Teglio and Marco Raberto. Housing market bubbles and business cycles in an agent-based credit economy. *Open-Assessment E-Journal, Vol. 8, 8. http://dx.doi.org/10.5018/economics- ejournal.ja.2014-8.*, 2014.

[11] Giorgio Fagiolo and Andrea Roventini. Macroeconomic policy in dsge and agent-based models redux: New developments and challenges ahead. *Journal of Artificial Societies and Social Simulation, 20(1)*, 2017.

[12] Irving Fisher. *Booms and Depressions - Some First Principles*. New York: Adelphi Company, 1932.

[13] Irving Fisher. The debt-deflation theory of great depressions. *Econometrica*, 1(4):337–357, October 1933.

[14] Irving Fisher. *100% Money*. The City Printing Company, New Haven, third edition, 1945. First edition (1935) available through ThaiSunset Publications, 2011.

[15] Irving Fisher, Paul Douglas, Frank D. Graham, Earl J. Hamilton, Willford I. King, and Charles R. Whittlesey. A program for monetary reform (mimeograph), July, 1939. Included in the Editor's Appendix to "100% Money by Irving Fisher", ThaiSunset Publications, 2011.

[16] Jay W. Forrester. Growth cycles. *De Economist 125(4), 525-543*, 1977.

[17] Jay W. Forrester. An alternative approach to economic policy: Macrobehavior from microstructure. *The MIT System Dynamics Group Literature Collection, System Dynamics Society, New York*, (D-4874):80–108, 1979.

[18] Jay W. Forrester. *The System Dynamics National Model: Macrobehavior from Microstructure. In: Milling P.M., Zahn E.O.K. (eds) Computer-Based Management of Complex Systems*. Springer Berlin, Heidelberg, 1989.

[19] Zoltan Jakab and Michael Kumhof. Banks are not intermediaries of loanable funds - and why this matters. Working Paper No. 529, Bank of England, May 2015.

[20] Nathaniel J. Mass Jay W. Forrester and Charles J. Ryan. The system dynamics national model: Understanding socio-economic behavior and policy alternatives. *Technological Forecasting and Social Change, 9(1–2), 51-68*, 1976.

[21] Robert E. Lucas Jr. Econometric policy evaluation: A critique. *Carnegie-Rochester Conference Series on Public Policy*, 1:19–46, 1976.

[22] Richard C. Koo. *The Holy Grail of Macroeconomics – Lessons From Japan's Great Recession.* John Wiley & Sons (Asia) Pte. Ltd., Singapore, 2009.

[23] Paul Krugman. It's baaack: Japan's slump and the return of the liquidity trap. *Brookings Papers on Economic Activities, 2: 137-205*, 1998.

[24] H.D MacLeod. *The Theory and Practice of Banking*, volume 2. Longman, Greens and Co., London, 1856.

[25] Silvano Cincotti Marco Raberto, Andrea Teglio. Debt, deleveraging and business cycles: An agent-based perspective. *Open-Assessment E-Journal, Vol. 6, 27, http://dx.doi.org/10.5018/economics-ejournal.ja.2012-27.*, 2012.

[26] Donella H. Meadows. The unavoidable a priori. In Jorgen Randers, editor, *Elements of the System Dynamics Method.* Pegasus Communications, 1980.

[27] Amar Radia Michael Mcleay and Ryland Thomas. Money creation in the modern economy. Quarterly bulletin, Bank of England, 2014, Q1.

[28] Bank of Japan. Quantitative and qualitative monetary easing and economic theory - speeh at the university of zurich in switzerland, 2017.

[29] Bank of Japan. Institute for Monetary and Economic Studies. *Functions and Operations of the Bank of Japan (in Japanese).* YUHIKAKU, 2011.

[30] Ronnie J. Phillips. *The Chicago Plan & New Deal Banking Reform.* M.E. Sharpe, Inc., London, New York, 1995.

[31] Hazhir Rahmandad and John D. Sterman. Heterogeneity and network structure in the dynamics of diffusion: Comparing agent-based and differential equation models. *Management Science, 54(5):998-1014*, May 2008.

[32] Christina D. Romer. What ended the great depression. *NBER Working Paper, 3829*, 1991.

[33] Masaaki Shirakawa. *Modern Monetary Policy in Theory and Practice: Central Banking and Financial Markets (in Japanese).* Nihon Keizai Shinbun, 2008.

[34] John D. Sterman. A behavioral model of the economic long wave. *Journal of Economic Behavior and Organization*, 6:17–53, 1985.

[35] John D. Sterman. The economic long wage: Theory and evidence. *System Dynamics Review*, 2(2):87–125, 1986.

[36] John D. Sterman. *Business Dynamics - Systems Thinking and Modeling for a ComplexWorld*. The McGraw-Hill Companies, New York, 2000.

[37] Joseph E. Stiglitz. Rethinking macroeconomics: what failed, and how to repair it. *Journal of European Economic Association, 9(4): 591-645*, 2011.

[38] Lars E. O. Svensson. Escaping from a liquidity trap and deflation: The foolproof way and others. *Journal of Economic Perspectives, 17(4): 145-66*, 2003.

[39] Murat A. Yulek Syed F. Mahmud, Kaoru Yamaguchi. *Money Matters: Some Puzzles, Anomalies and Crises in the Standard Macroeocnomic Model*. Peter Lang GmbH, 2017.

[40] Peter Temin. The great depression. Technical report, NBER Working Paper Series on Historical Factors in Long Run Growth,, Historical Paper 62, 1994.

[41] Ludwig von Mises. *The Theory of Money and Credit*. Indianopolis: Liberty Fund, 1912.

[42] Richard A. Werner. A lost century in economics: Three theories of banking and the conclusive evidence. *International Review of Financial Analysis (ELSVIER), 46:361-379*, page 19, 2016.

[43] Kaoru Yamaguchi. *Beyond Walras, Keynes and Marx – Synthesis in Economic TheoryToward a New Social Design*. Peter Lang Publishing, Inc., New York, 1988.

[44] Kaoru Yamaguchi. *Money and Macroeconomic Dynamics – Accounting System Dynamics Approach*. Japan Futures Research Center, Awaji Island, Japan (Edition 3.1, 2016 is available at http://www.muratopia.org/Yamaguchi/MacroBook.html), 2013.

[45] Kaoru Yamaguchi and Yokei Yamguchi. Heads and tails of money creation and its system design failures – toward the alternative system design –. *Proceedings of the 34th International Conference of the System Dynamics Society, Delft, The Netherlands*, July 18th 2016.

List of Figures

Appendix 1: Stock-Flow Model Diagrams

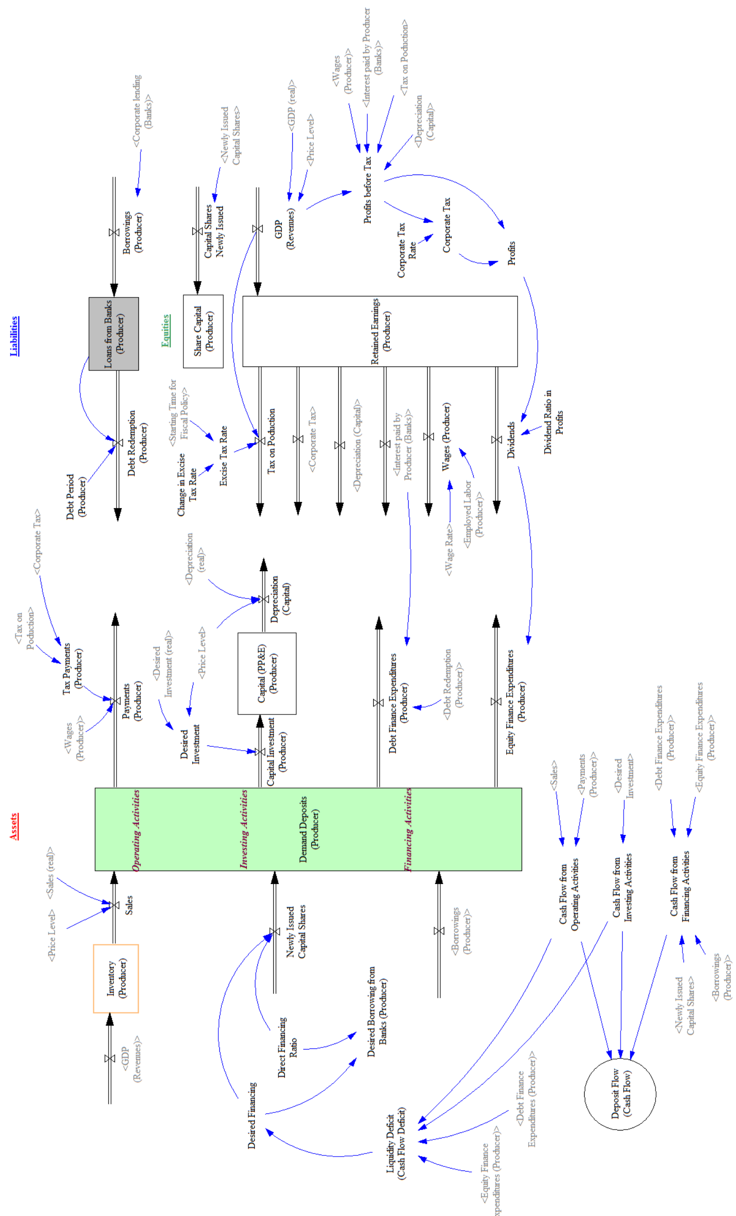


Figure 16: Balance sheet of Producer & Transactions

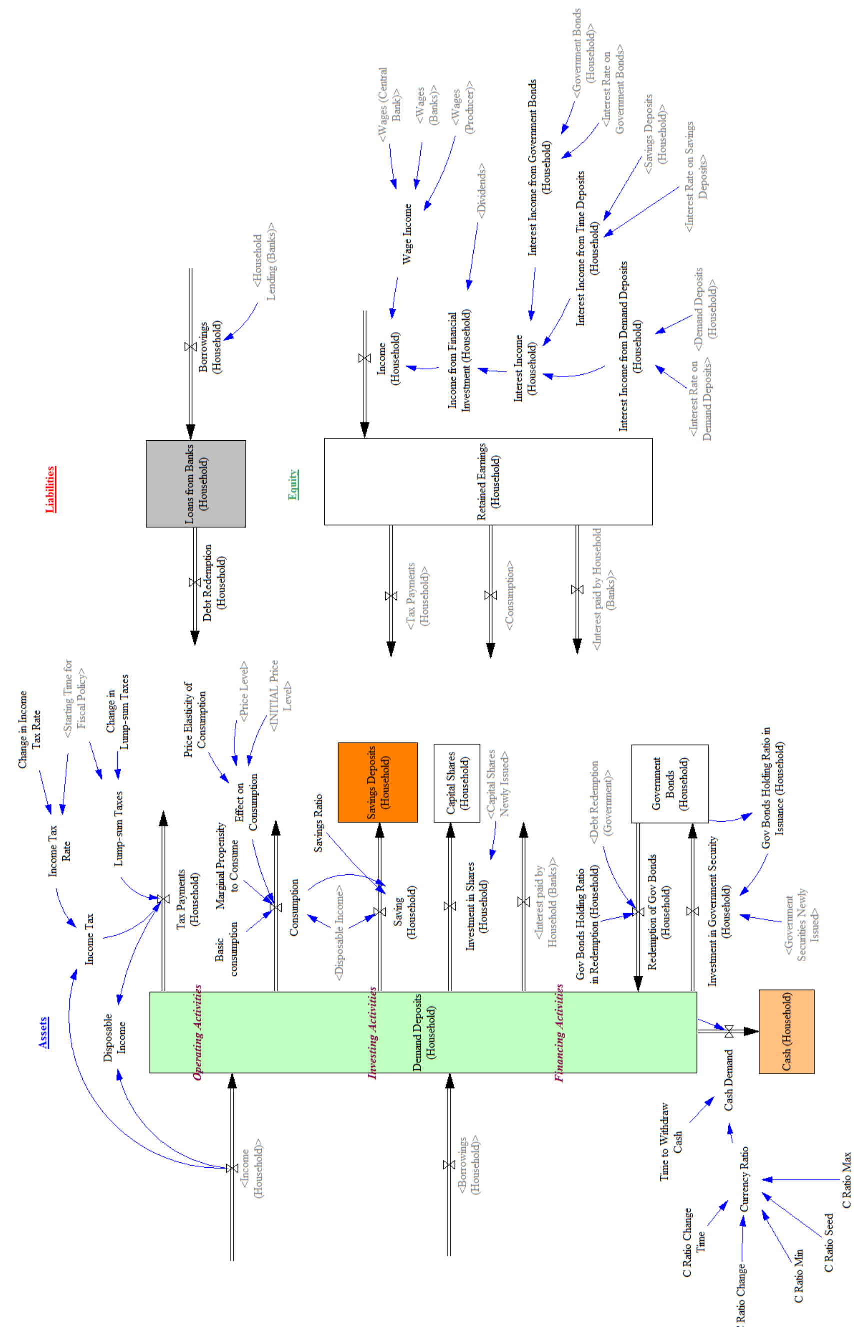


Figure 17: Balance sheet of Households & Transactions

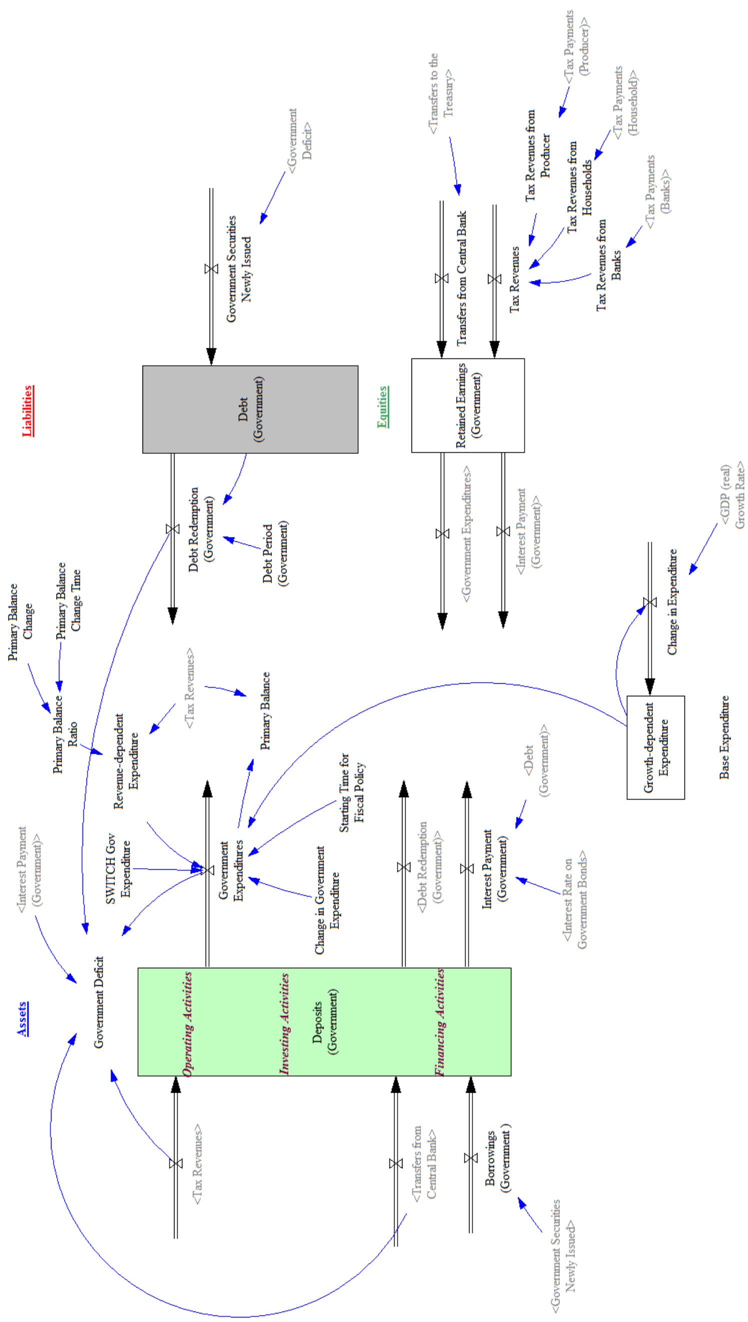


Figure 18: Balance sheet of the Government & Transactions

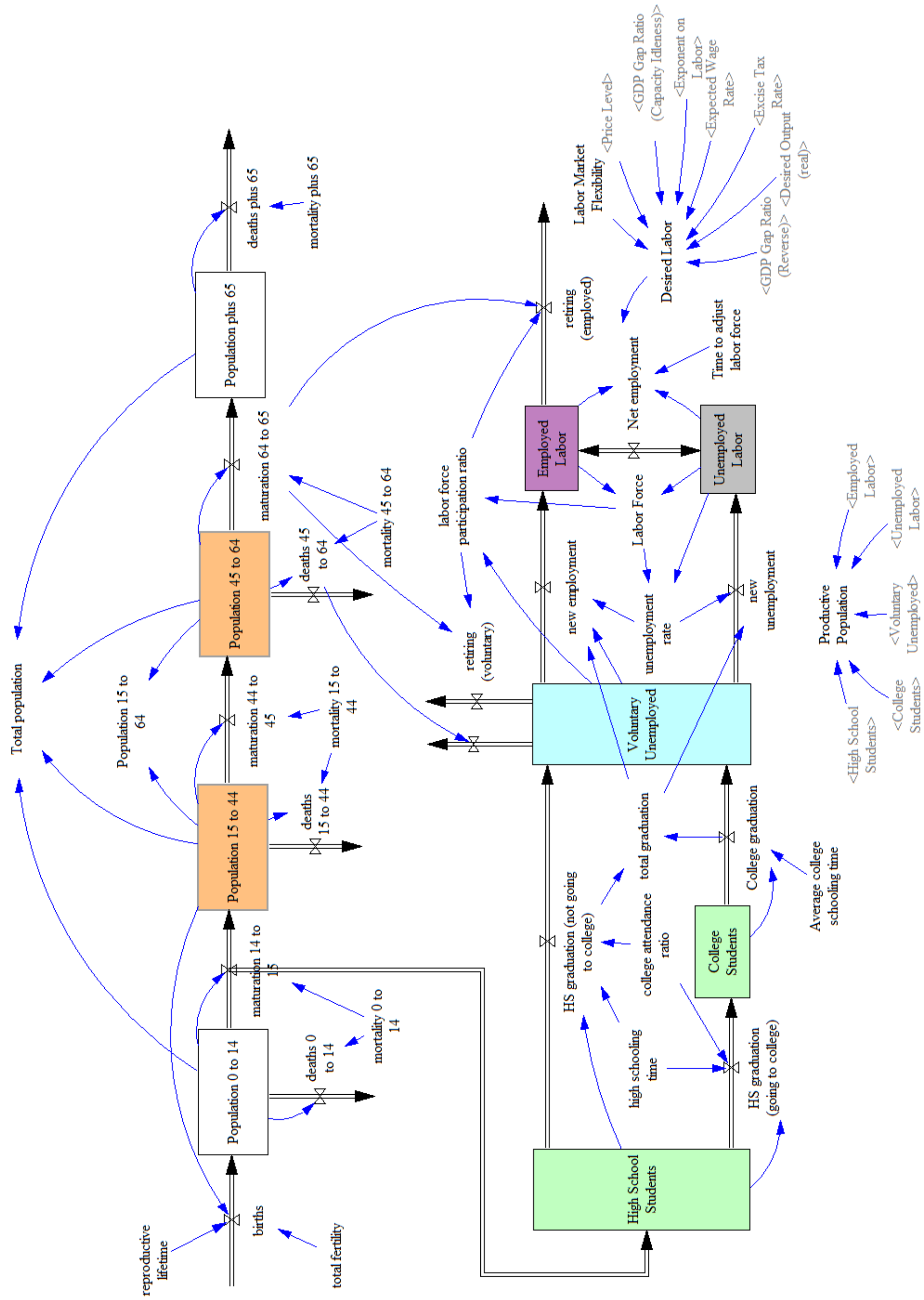


Figure 19: Population Dynamics & Labor Market