

# Developing an ASD Macroeconomic Model of the Stock Approach

- With Emphasis on Bank Lending and Interest Rates -

by

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Thesis

Submitted to the Department of Geography, University of Bergen

in Partial Fulfillment of the Requirements for the Degree of

Master of Philosophy in System Dynamics,

M. Phil in System Dynamics (Università degli Studi di Palermo, Italy),

M. Sc. in Business Administration (Radboud Universiteit, the Netherlands)

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**June, 2017**

## **Abstract**

The financial crisis in 2008 evidenced an over-simplification of the role of banks made in the majority of macroeconomic models. Based on Accounting System Dynamics (ASD) modeling approach, the current research presents a model that incorporates banks as creators of deposits when making loans as opposed to the conventional view of banks as intermediaries of existing money. The generic model thus developed consists of five sectors; production, household, banking, government and central bank to better understand interrelationships among five sectors and to explore how monetary and production sector interact. The model turns out to produce diverse macroeconomic behaviors driven by interactions of reinforcing and balancing feedback loops. Some of them are: 1. Variability of money stock under stable base money due to endogenous deposit creation, 2. Short-term business cycles triggered by two different sources, 3. Temporary alleviation of GDP gap by monetary easing policy and its limitation for counteracting deflationary trend, 4. Different macroeconomic effects induced by the same fiscal policy implemented under different economic conditions, 5. Macroeconomic instabilities triggered by credit crunches and a shock in currency holding ratio.

Simulation experiments under different scenarios highlight the importance of building a macroeconomic model where banks supply the majority of money stock. We believe that this generic ASD macroeconomic model of the stock approach could provide a foundation for actual macroeconomic analyses based on historical economic data.

## **Acknowledgements**

Firstly, the thesis has not been possible without the commitment made by the supervisor Dr. David Wheat. His thorough feedback comments, and constructive critics led me to learn much more during the research. My next thanks goes to people who are committed to the EMSD program. I have been supported financially by the consortium's partial scholarships during my study. Looking back two years from now, I could not have experienced this rewarding joint masters degree program without the very decision made by the program. I would also like to thank Dr. Kaoru Yamaguchi, who provided me feedback comments as the original developer of the macroeconomic model that is used as a basis of the stock approach model developed in this research project.

My last gratitude goes to my family and friends. I am grateful for spiritual supports and encouragements they have given me throughout my study. Gassho.

# Developing an ASD Macroeconomic Model of the Stock Approach

– With Emphasis on Bank Lending and Interest Rates –

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**Keywords:** Money, Deposit Creation, Fractional Reserve Banking System, Flow of Funds, Aggregate Demand, Aggregate Supply, Monetary Policy, Fiscal Policy, Government Debt, Population Dynamics

## Abstract

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\*This paper was submitted to the Department of Geography, University of Bergen on July 30th, in partial fulfillment for the requirements of Joint European Master Programme in System Dynamics: <http://europeansystemdynamics.eu>. The author was supported by the program's partial consortium scholarship and is grateful to the opportunity, which enabled him to pursue the current research.

# 1 Introduction

The global financial crisis (GFC) evidenced an over-simplification of the basic role of banks reflected in mainstream macroeconomic models. Number of critics emerged as to how standard macroeconomic models do not adequately incorporate interactions of financial and real economy.<sup>1</sup> More specifically, a mainstream approach to incorporate banks has been to represent them as a neutral channel connecting savers and borrowers in the economy. After the GFC, however, the view of banks as mere intermediaries of money, and the deposit multiplication process under fractional reserve banking system have been re-examined by both monetary authorities and academics. Bank of England [7, 2014] in particular pointed out the conventional view of banks as intermediaries of money as a 'common misconception' and explained how deposits, which constitutes the large portion of money supply, are created by commercial banks in the act of lending by using graphical illustrations to explain corresponding changes in commercial bank's balance sheets. Werner [12, 2015] conducted an extensive review on literatures from macroeconomics, banking, finance and showed that the majority of them regard banks as intermediaries of money. Furthermore, the same research provided an empirical study that rejects the view of banks as intermediaries and supports the view of banks as creators of deposit, which turned out to be an older and original view of banking business recognized by bankers and academics nearly a century ago.<sup>2</sup> The researcher then concluded that recognizing banks as creators of deposit becomes crucial and must be the basis for developing a theory to better examine macroeconomic dynamics.

Despite the growing number of literatures shifting towards the original and older view of banks as creators of deposits, accounting mechanics underlying bank lending by deposit creation has received insufficient examination in macroeconomic theory and has rarely been reflected into its analytical framework. Yamaguchi and Yamaguchi [16, 2016] built two simple accounting system dynamics (ASD) models to examine differences in behaviors of deposit creation process based on two different views of banking respectively; *banks as intermediaries of money* and *banks as creators of deposit*. Naming the former and latter modeling approach as flow and stock approaches of modeling banks respectively, their simulation-based experiments demonstrated that two approaches produce an identical system behavior of monetary expansion and contraction. The researchers then analyzed that this instability of money stock is generated by the underlying system structure of fractional reserve banking that causes endogenous creation and destruction of bank deposits, banking crisis and accumulation of government debt. However, simple models used in their simulation experiments left out production sector from its structure, leaving a theoretical

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<sup>1</sup>See Mahmud, Yamaguchi and Yülek [11, 2017], for example, for a critical review on the theoretical evolution behind the standard macroeconomic models (SMM) and a summary of highly unrealistic assumptions made in the SMM, such as a family of Dynamic Stochastic General Equilibrium (DSGE) models.

<sup>2</sup>For example, Werner [12, 2015] references Macleod [5, 1856] as an authentic example of the older view that bank lending creates new deposits at the moment of bank loan transactions.

question as to how endogenous expansion and contraction of money stock and determination of GDP interact each other. This also constitutes a theoretical gap between the structural analysis on monetary instability done by Yamaguchi et.al [16, 2016] and qualitative analysis on macroeconomic instability such as the debt-deflation theory of Great Depressions put forward by Fisher [2, 1933]. The current research attempts to develop a macroeconomic model by applying the stock approach modeling of banks in order to better understand and analyze interrelationships among banking and determination of GDP.

## Structure of the Paper

This paper is organized as follows: In Section 2 we strictly define what is money and what is not in order to incorporate the actual process of deposit creation by commercial banks into a macroeconomic model. Section 3 briefly revisits the differences between the flow and stock approaches of modeling banks with an emphasis on accounting mechanics underlying the two approaches. In Section 4, we summarize characteristics of the basic modeling methods employed in the current research. Then in section 5, qualitative model descriptions are provided with a focus on structural and behavioral assumptions made in the model. In section 6, equations of the core part of the model are explained in detail, followed by model tests in section 7. In section 8, we run a base run simulation and analyze the model behavior with the help of a causal loop diagram. In section 9, different scenarios are examined to explore behaviors of the stock approach model. Section 10 summarizes the current research.

## 2 Money and Functional-Money

To reflect the actual process of bank lending into a macroeconomic model, it becomes crucial to distinguish money from functional money (bank deposits). Therefore, we begin by strictly defining what money is, classify and measure different types of monetary aggregates.<sup>3</sup>

### 2.1 Definition of Money

#### 2.1.1 Money as Legal Tender

Money is nothing but information of value which can be exchanged for goods and services, and the stability of its purchasing power must be maintained over a period of time. Information needs media to be carried with. As such, it does not concern how it is represented on what kind of media, except that its unit of measure is defined by law (legal tender) as stated by Aristotle (384-322 BC) in ancient Greece. He observed money as follows:

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<sup>3</sup>The basic outline of discussion in this section is based on Yamaguchi et.al [16, 2016].

and this is why it has the name *nomisma* - because **it exists not by nature, but by law (*nomos*)** and it is in our power to change it and make it useless [17, p.34].

Contrary to his recognition, money has historically been explained in terms of its physical properties, even though it has changed its form of media from physical to an abstract one through the development of information technology.

### 2.1.2 Money as Commodity

Today, as we see from Table 1, almost all of medium of exchange used in daily transactions are expressed in the form of deposits (electronic digits) at commercial banks, starting roughly around 1970's. However, Adam Smith (1723-1790), known as the father of economics, reversed the definition of money by Aristotle as follows:

By the money price of goods it is to be observed, I understand always, *the quantity of pure gold and silver* for which they are sold, without any regard to denomination of the coin. [17, p.313].

In this way, Adam Smith defined the money as commodity and reversed the definition of *money as legal tender*. This erroneous logical step by the father of economics seemed to have emanated wide-spread definition of *money as commodity*. Advancing his idea more axiomatically, many macroeconomics textbooks define money as the entity that meets the following three functions; (1) unit of account, (2) medium of exchange and (3) store of value. According to this axiom, gold and silver can be best qualified as ideal money because, *by nature*, their physical properties perfectly meet the three functions of money. This recognition of money as legal tender becomes crucial in separating money from functional-money as discussed below.

### 2.1.3 Bank Deposits as Functional-Money

Almost all economy today operates under the fractional reserve banking system. This is a particular financial system in which commercial banks are legally allowed to create deposits (which are recorded as liability on bank's balance sheet) out of nothing when they make loan contracts with borrowers.

Are bank deposits *money as legal tender*? According to Masaaki Shirakawa, a former governor of the Bank of Japan, the answer is negative.

Contrary to the central bank notes, creditors can refuse to accept bank deposits as the payments of debt obligations because of credit risks associated with bankruptcies of debtors' banks. However, in normal times, bank deposits **function as money** because of creditors' confidence that bank deposits can be converted to central bank notes [9, p.13] (translated by the authors).

Commercial bank deposits are neither *money as legal tender* nor *currency*. This is why they are classified as *functional-money* in Table 1.

## 2.2 Classification of Money

From our strict definition of money as legal tender, table 1 classifies different types of money and functional-money used in human history.

Classification of Money		
Media	Money as Legal Tender	Functional-Money
Non-metal Commodities	Shell, Cloth (Silk) Woods, Stones, etc	
Metal Coinage	Non-precious Metal Coins Gold, Silver & Copper Coins	Metal Ingots (such as Gold)
Paper Notes	Goldsmith Certificates Central Bank Notes	Bank Notes (Free-Banking Age)
Digital Accounts Electronic Cards	Electronic (Digital) Cash (Intangible Digits)	Deposits (Credits by Loans)

Table 1: Classification of Money and Functional-Money

## 2.3 Measurement of Monetary Aggregates

By defining bank deposit as a different medium of exchange from money, let us now explain different measurements for monetary aggregates. Money that are used in daily transactions is called *money stock*. It is defined as

$$\text{Money Stock} = \text{Currency in Circulation} + (\text{Commercial Bank}) \text{ Deposits} \quad (1)$$

Money stock thus defined is the total amount of money available in the economy, regulating transactions and economic activities. *Currency* is strictly defined as

$$\text{Currency Outstanding} = \text{Coins} + \text{Central Bank Notes} \quad (2)$$

Another important measure of monetary aggregates is base money or monetary base. It is defined as

$$\text{Base Money} = \text{Currency Outstanding} + (\text{Central Bank}) \text{ Reserves} \quad (3)$$

For example, base money in Japan is strictly defined in terms of government coins, bank of Japan notes and reserves at the BoJ (which are essentially electronic digits recorded on digital ledgers maintained at the bank's data center), all of which have no intrinsic values. Currency is the same as "cash", and by definition it is *legal tender* in the sense that no one can reject payments of debt made with them.



## 2.4 Issuance of Base Money

Let us look at how and when base money is issued in today's economy. As we have seen in the previous section, the government of Japan issues coins. Bank of Japan prints its notes and supplies reserves to commercial banks when needed for achieving its monetary policy objective. For the sake of simplicity, let us aggregate coins and notes as currency. Base money in Japan is issued primarily by the bank of Japan by way of supplying reserves, given the very small proportion of government coins relative to the total amount of base money. Central bank issues money only by purchasing existing assets held by financial institutions that maintain deposit account at the central bank.

Table 2 below illustrates an example where reserves are supplied to banks through asset purchase operation using the T-account method in double-entry bookkeeping.

Central Bank		Commercial Banks	
Debit (Asset)	Credit (Liability)	Debit (Asset)	Credit (Asset)
Gov. Bonds (+)	Reserves (+)	Reserves (+)	Gov. Bonds (-)

Table 2: Issuance of Base Money through Asset Purchases

As a result of this transaction, one could see that the amount of reserves (part of base money) increases and the balance sheet of central bank increases simultaneously.

## 2.5 Printing of Central Bank Notes

As we saw above, additional base money is issued and put into circulation not by printing notes, but when central bank supplies reserves to commercial banks. Unless there is literally a helicopter money as a way to put into circulation, printing of bank notes and an increase in base money is a separate phenomenon. To be more specific, new bank notes are printed when commercial banks, faced with growing demand for central bank notes by depositors, withdraw their deposits at the central bank by cash.<sup>4</sup> In order to accommodate the growing demand for bank notes by commercial banks, the Bank of Japan adjusts the available cash by printing new notes to meet the expected increase in bank notes demanded by commercial banks. Therefore, in real world, printing notes occurs as a result of conversion from central bank reserves (electronic digits) into bank notes made by commercial banks, which does not bring any changes in the amount of base money.

<sup>4</sup>In such occasions, demand for notes by commercial banks from the central bank increases. For example, this occurs during vacation times, or at the end of the year in an economy where people continue to use physical cash during cultural events. These are the typical seasonal factors responsible for periodical increase in bank notes demand such as in Japan [8].

A transaction shown in Table 3 below records changes in the balance sheets of the central bank and commercial banks when commercial banks withdraw their reserves by bank notes in preparation for expected growing demand for cash by depositors.

Central Bank		Commercial Banks	
Debit (Liability)	Credit (Liability)	Debit (Asset)	Credit (Asset)
Reserves (-)	Currency Outstanding (+)	Vault Cash (Bank Notes) (+)	Reserves (-)

Table 3: Withdrawal of Bank Notes by Commercial Banks

Consequently, the size of balance sheets of both central bank and banks remain the same before and after the transaction. No change has occurred to base money either.

### 3 Flow and Stock Approaches of Modeling Banks

Two different theories coexisted as to how banks actually operate its lending (investment) business under the fractional reserve banking system. Yamaguchi & Yamaguchi [16, 2016] investigated the two different theories by applying accounting system dynamics (ASD) method to model transactions of bank lending and deposit creation process in each theory. The difference between the two becomes clear by considering accounting treatment of a transaction where a bank(s) make loans and translate it into a stock and flow diagram.

#### 3.1 Banks as Intermediaries of Money: Flow Approach

The first view of banking treats a bank(s) as an intermediary of money. Table 4 below illustrates how a transaction of a bank(s) making loan should be recorded if they are lending funds that they have acquired beforehand. Consequently, in this view, a transaction of making loan to a borrower(s) should results in changes in asset side of the bank's balance sheet following double-entry bookkeeping rules.

Commercial Banks		Borrowers	
Debit (Asset)	Credit (Asset)	Debit (Asset)	Credit (Liability)
Loans Receivable (+)	Reserves (or Vault cash) (-)	Reserves or Cash (+)	Loans Payable (+)

Table 4: Lending out existing money when making loans

The above accounting treatment of bank lending transaction can be illustrated more intuitively by translating it into a stock and flow diagram. Figure 1 illustrates a translation of the same journal entries shown in Table 4 into a stock and flow diagram representing commercial bank's balance sheet.

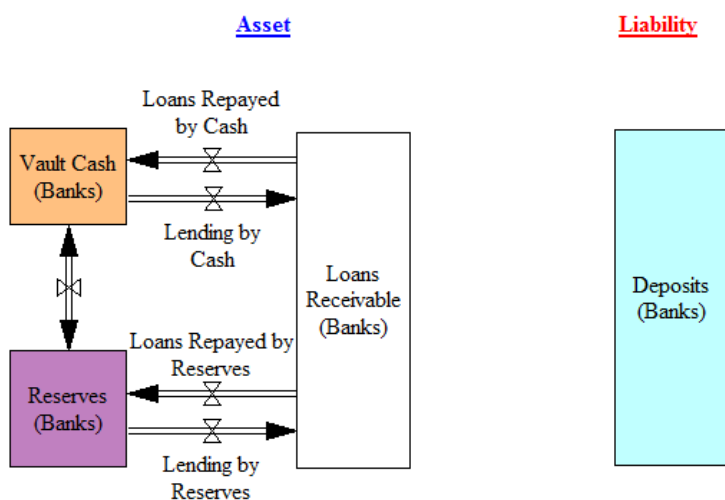


Figure 1: Flow approach of modeling bank lending

This implies that banks lend out either (vault) cash or reserves only with the amount they hold while maintaining the reserve requirement. There is no increase in deposit outstanding in the economy at the moment of the loan transaction in the flow approach. Merely the existing *money* (bank's vault cash or reserves) were lent out.<sup>5</sup> According to the recent report by Bank of England staffs and other literatures supported by an empirical evidence, this is a *common misconception* of how banks operates in their business.<sup>6</sup>

<sup>5</sup>This records the end of a single transaction as illustrated in the Table 4. Under the flow approach, deposits in the economy would increase when borrowers redeposit their newly borrowed money with banks. However, this transaction of redepositing money after borrowing is a separate transaction by itself, which should not be considered simultaneously with the bank lending transaction following the bookkeeping rules.

<sup>6</sup>Another implication of flow approach is that borrowers from the bank receive money by

### 3.2 Banks as Creators of Deposit: Stock Approach

#### Creation of Deposits

Let us now revisit the stock approach of modeling bank lending under the fractional reserve banking system. Contrary to the textbook explanation of banks as intermediaries of money, deposits are newly created out of nothing. This transaction is recorded by the following journal entry:

Commercial Banks		Borrowers	
Debit (Asset)	Credit (Liability)	Debit (Asset)	Credit (Liability)
Loans (+) Receivable	Deposits (+)	Deposits (+)	Loans Payable (+)

Table 5: Creating Deposits when making Loans

Transactions of bank lending thus increase loans receivable (asset) and deposits (liability) on the balance sheet of commercial banks simultaneously. Similarly, let us translate this journal entry into a stock and flow diagram. Figure 2 illustrates how stock approach of modeling bank lending describes changes in the bank's balance sheet after loans are made.

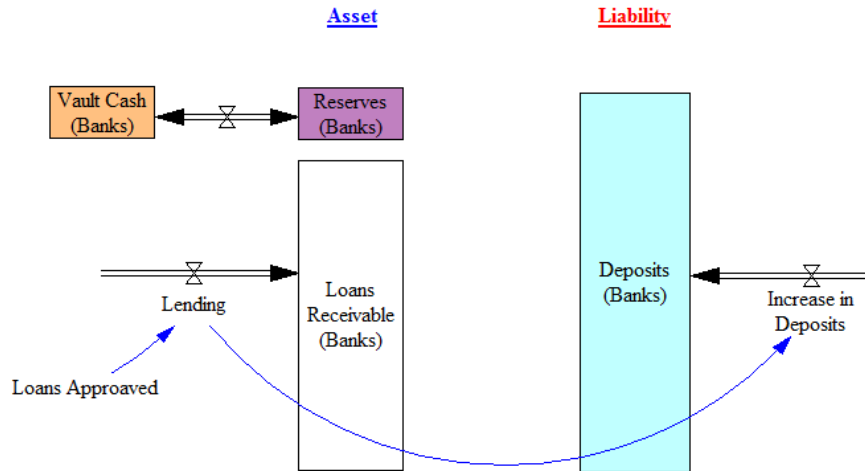


Figure 2: Stock Approach of modeling Bank Lending

either cash or central bank reserves. This is in contrast to what we observe in the bank lending transactions in reality. Most borrowers do not have reserves account at the central bank except financial institutions and particular non-financial institutions under the current payment system.

Unlike the flow approach case, new bank loans lead to creation of new deposits at the moment of the loan transaction. Brand new deposits created by this way constitute the majority of money supply of the economy. Hence, bank lending transactions modeled by flow and stock approaches are two different descriptions of economic activity.

## Destruction of Deposits

Deposits are newly created in the act of bank lending. Bank deposits are essentially bank's promises to meet the depositor's demand for withdrawal by cash. What happens, then, when loans are repaid? Table 6 below illustrates how this transaction of loan repayment is recorded.

Commercial Banks		Borrowers	
Debit (Liability)	Credit (Asset)	Debit (Liability)	Credit (Asset)
Deposits (-)	Loans Receivable (-)	Loans Payable (-)	Deposits (-)

Table 6: Destruction of Deposits upon Redemption of Loans

Similarly, the above transaction in Table 6 is translated into a stock and flow diagram as shown in Figure 3 below.

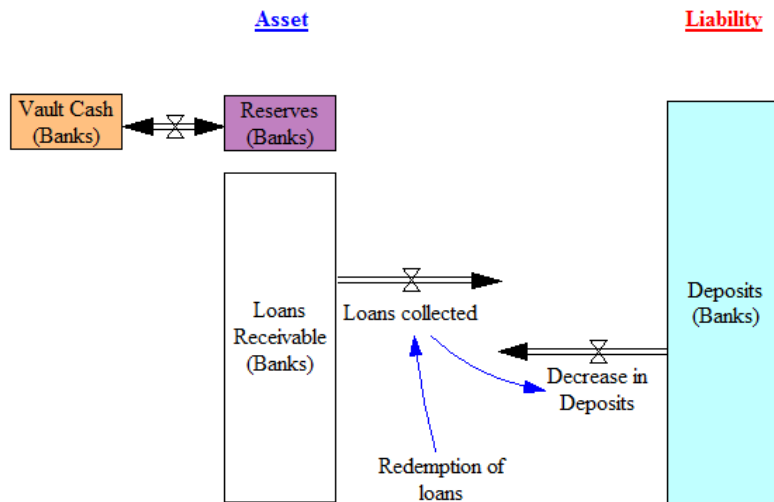


Figure 3: Stock Approach of modeling Bank Loan Repayments

Yamaguchi and Yamaguchi [16, 2016] developed two simple ASD models based on the flow and stock approaches. Their simulation experiments demonstrated that both models produce identical behaviors converging to the same numerical values of money stock when banks are assumed to make maximum amount of loans under a certain required reserve ratio. However, models used in the analysis did not have real production sector, leaving the analysis only applicable as far as money creation process is concerned. What, then, is the implication of the flow and stock approaches in considering macroeconomic theory?

### 3.3 Different Constraints on Bank Lending Amounts

The flow approach models banks as lending money out of funds which they must have acquired beforehand, whereas the stock approach models bank lending as creation of new deposits against which banks must meet the cash demand in case borrowers or depositors wish to withdraw them by money. The two economic events are totally different and imply different constraint of the amount of loans banks can lend or create. Let us see this in more detail.

Under the flow approach banks are faced with liquidity constraint by either the amount of cash or reserves they hold with central bank in order to conduct their lending business. In other words, should the demand for bank loans ("desired borrowings") exceeds the amount they currently hold, banks can only lend out money to that extent. Therefore, a necessary condition for the amount of bank lending under the flow approach must be expressed as follows

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

assuming that banks lend out by cash and hold just as much reserves they need to achieve required reserves.<sup>7</sup>

On the other hand, banks increase loans receivable by creating corresponding amount of deposit under the stock approach. Hence, under the stock approach, a necessary condition for bank lending at a macroeconomic level must be determined as follows

$$\text{Bank Lending} = \text{MIN}(\text{Desired Borrowing}, \text{Maximum Loanable Funds})$$

Thus, our model based on the stock approach employs this type of bank lending condition.<sup>8</sup>

## 4 Research Method

### 4.1 System Dynamics as Methodological Foundation

Meadows [6, 1980] provides an in-depth look into the characteristics of models developed with system dynamics approach, their advantages as well as limita-

<sup>7</sup>To be more precise, the condition should be  $\text{MIN}(\text{Desired Borrowing}, \text{Cash}_{\text{Banks}}/\text{Lending Delay Time})$  to keep unit consistency in system dynamics model.

<sup>8</sup>The condition is explained in more detail in section 6.6.2.

tions in comparison to other major modeling approaches such as econometrics, input-output analysis and optimization models. To put into a wider perspective, it is relevant to make a note that Jay W. Forrester, who developed the foundation of system dynamics, brought together ideas from three fields; control theory in engineering, cybernetics and organizational theory.

In the context of macroeconomic modeling, the following lists some of analytical advantages of system dynamics modeling approach:

- Disequilibrium analysis
- Causal and feedback perspectives
- Capability to describe macro-behaviors from micro-structure
- Capability to model bounded rationality and psychological variables

## 4.2 Accounting System Dynamics (ASD)

The current research is build upon the analytical principles of Accounting System Dynamics (ASD) and utilizes its framework extensively in the modeling section. Yamaguchi [13, 2003] proposed the Principle of Accounting System Dynamics, a simulation modeling method that combines Accounting System<sup>9</sup> and System Dynamics<sup>10</sup>. Employing the ASD modeling method becomes effective as the number of transactions increases. The method also helps modeler to be always mindful about errors in transaction consistency that are examined by balance sheet and flow of funds tests, which are covered in section 7.<sup>11</sup>

## 4.3 A Computer Simulation Program

At the core of our simulation-based analysis, we utilize the system dynamics computer simulation program called Vensim. The use of simulation program makes it graphically easier to develop and analyze dynamic feedback models.<sup>12</sup>

# 5 The Model

Qualitative descriptions of the model with a focus on structural and behavioral assumptions are explicated at the eagle's eye level.

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<sup>9</sup>A robust double-entry bookkeeping foundation for organizing economic transactions

<sup>10</sup>A dynamical foundation of differential equation in natural science.

<sup>11</sup>The reader should be noted here that the stock-flow consistent models are a different family of macroeconomic models from ASD macroeconomic models. The primary difference is the use of transaction matrices in combination with a non-system dynamics modeling methods in the former case and system dynamics modeling with double-entry bookkeeping principles embedded in modeling financial part of system dynamics model in the latter.

<sup>12</sup>Details about the simulation software program is available at a official webpage of the software: <http://vensim.com>.

## 5.1 An Overview of Macroeconomic System

Figure 4 illustrates an overview of our macroeconomic system, and shows how each sector interacts with one another through various macroeconomic transactions. The figure also describes circular flows of money and bank deposits. Foreign sector is excluded from the current analysis. Therefore, our current ASD macroeconomic model is a representation of a closed economy.

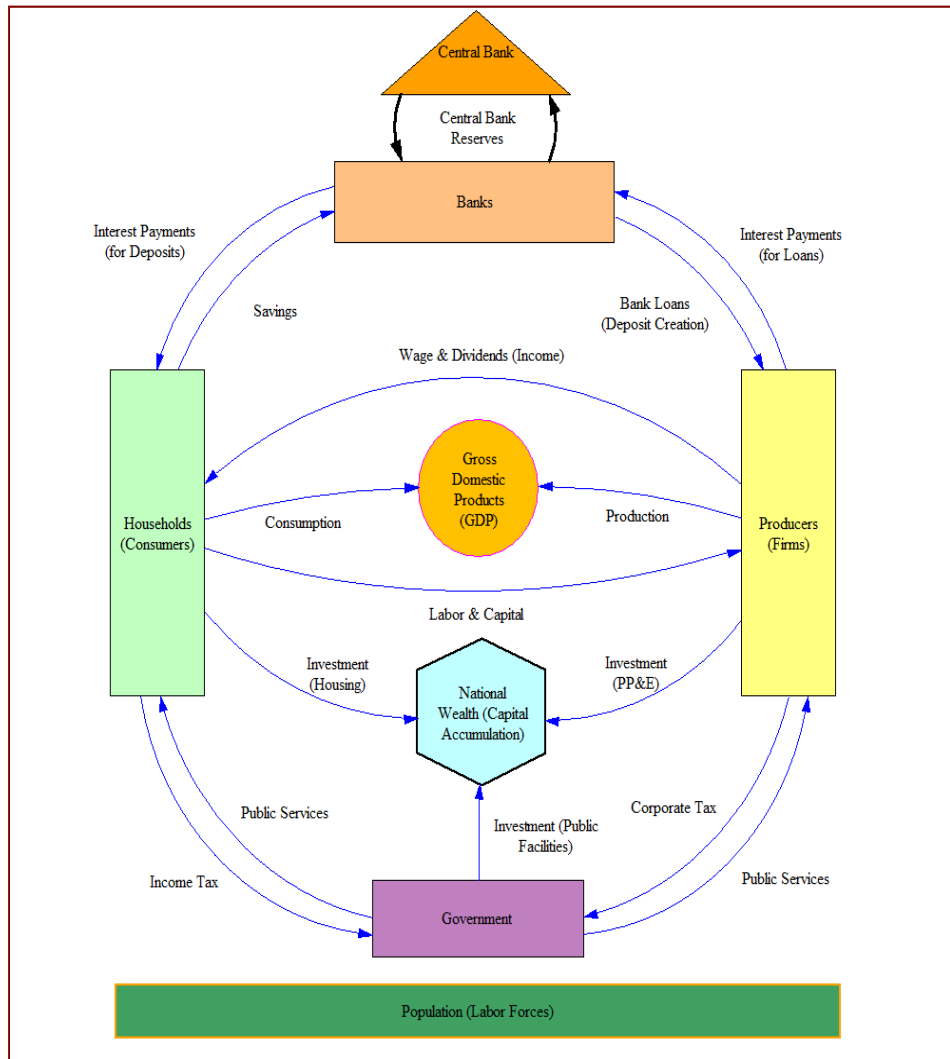


Figure 4: An Overview of Macroeconomic System



## 5.2 Structural Assumptions

### 5.2.1 New Features

The model newly developed in this research is based on the ASD model originally developed and presented in Chapter 9 of Yamaguchi [15, 2013]. The original model is based on the flow approach and models banks as intermediaries of money. Hence, in this model of the stock approach, major structural changes were made from the original flow approach model as follows:

1. Incorporation of the stock approach modeling of bank lending.
2. Interest determination based on the supply and demand relationship of central bank reserves.

According to item 1, the original model of Yamaguchi [15] was revised to reflect bank lending where new deposits are created. Additionally, our model presents two separate flows of money (such as cash, reserves) and bank deposits (functional money) as explained in more detail in the next section. This separate flows of money and bank deposits reflect how bank deposits are transferred among different macroeconomic sectors in today's payment system, which are ultimately processed by the central bank. To achieve this, the model newly introduces government deposit account held at the central bank, connecting non-bank sectors (i.e. household and producers sector) with the government through the new government deposit account at central bank. This will increase traceability of base money flowing within the liability side of the central bank's balance sheet. Details of transactions among five sectors and balance sheets are presented in the following section 5.3.

Regarding the item 2, a new approach of interest determination is introduced to our model of the stock approach. This is done by considering supply and demand relationship of central bank reserves, which is in turn affected by a number of factors in the model. The new interest determination employed in the model is an aggregate representation of, say, the call money market of Japan or federal funds market in the U.S. This enables us to incorporate realistic transmission mechanism of monetary policy into the model in which central bank can control the supply of reserves implemented through market operations.

### 5.2.2 Fractional Reserve Banking System

Table 7 below summarizes the structure of the fractional reserve banking system reflected in the model. It is a fully centralized system in which base money is issued by a central bank and bank deposits (functional-money) are created by commercial banks. Under the fractional reserve banking system, the legal reserve requirement imposes maximum loanable amount of funds on banks, which is dynamically determined by certain required reserve ratio and bank deposits outstanding at the moment of lending. A system in general consists of both a physical structure and decision rules used by the people in the system [10,

2000]. This is a legal part of structure which imposes an upper-limits to maximum amount of deposit creation in the economy as a whole.

	<b>Fractional Reserve System</b>
Issuer of Money	Central Bank
Creator of Deposits	Commercial Banks
Bank Deposits	Fractionally Reserved at the Central Bank
Issuance and Creation of Money Supply	Reserves: by Central Bank Deposits: by Bank Loans Currency: by the Government and CB
Nature of Money	Interest-bearing Debt
Economic Policies	Monetary Policy: Central Bank Fiscal Policy: The government

Table 7: Structure of Fractional Reserve Banking System

### 5.2.3 A Closed Economy

Our model assumes that the economy is closed, circulating within itself. Thus no world exists outside of the economy. Therefore, any feedback effects resulting from foreign exchange dynamics are left out from the current analysis. Instead, we focus on macroeconomic dynamics growing out of interactions among five sectors as described below.

## 5.3 Transactions among Five Sectors

Let us now describe major transactions among producers, consumers, government, banks and central bank. Contrary to the original flow approach model where cash was used as the primary means of payment, demand deposits are used as the primary means of payment in the stock approach model.

### Producers

Major transactions of producers are summarized as follows as illustrated in Figure 5.

- To maximize their profits, producers make capital investments and produce output called GDP (revenues), which are first recorded as inventories on their balance sheet.
- Aggregate demand is the sales of producers. Thus, sales becomes their sales revenue which depletes inventories. Producers receive the payments by 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 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 as dividends based on dividends ratio. Shareholders are households in the current model.
- Producers are thus constantly in a state of liquidity deficits. To continue making desired investment, therefore, they ask for loans from banks and pay accrued interests (indirect financing) or choose to issue capital shares (direct financing).

## Households

Transactions of households are summarized as follows as illustrated in Figure 6.

- Households receive wages and dividends from other sectors as part of their total income.
- Financial assets of households consist of demand and time 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 as illustrated in Figure 7 are summarized as follows.

- 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.

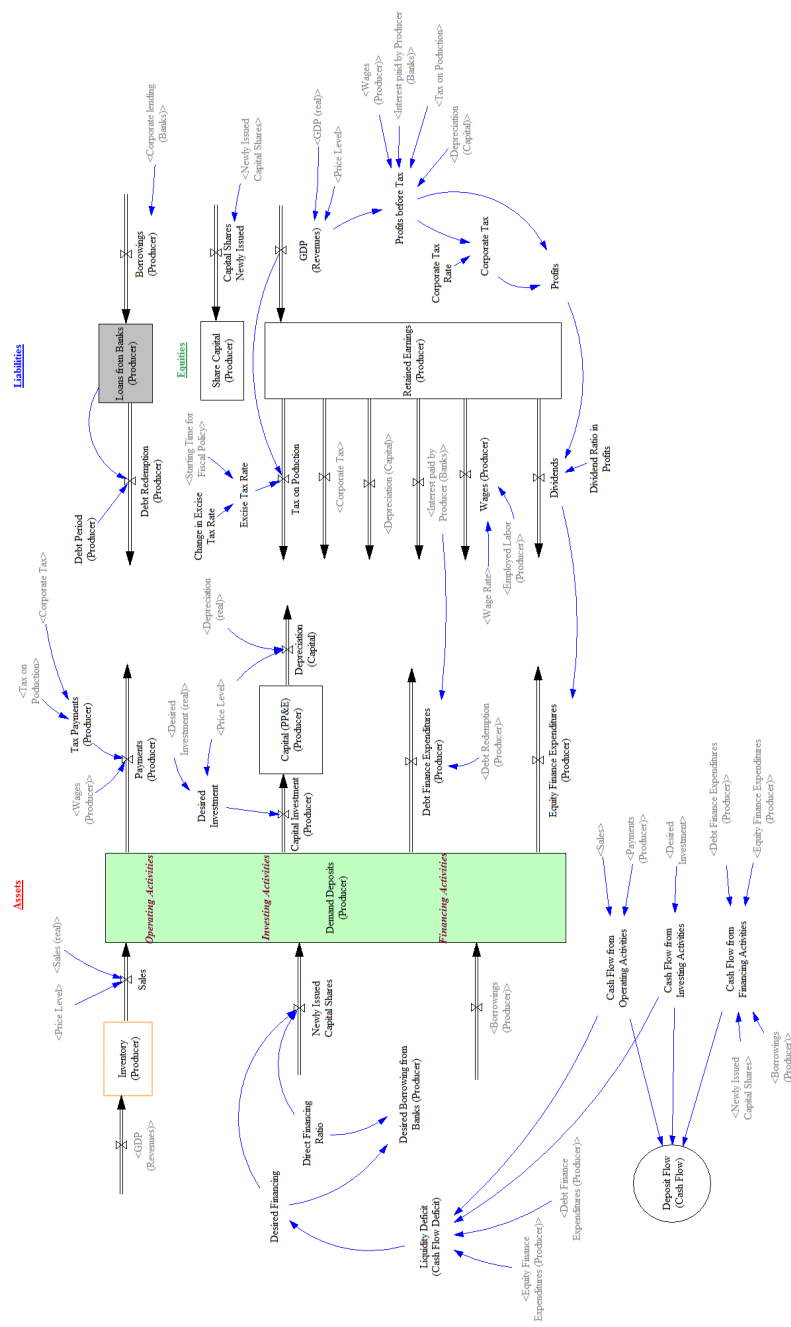


Figure 5: Transactions of Producers

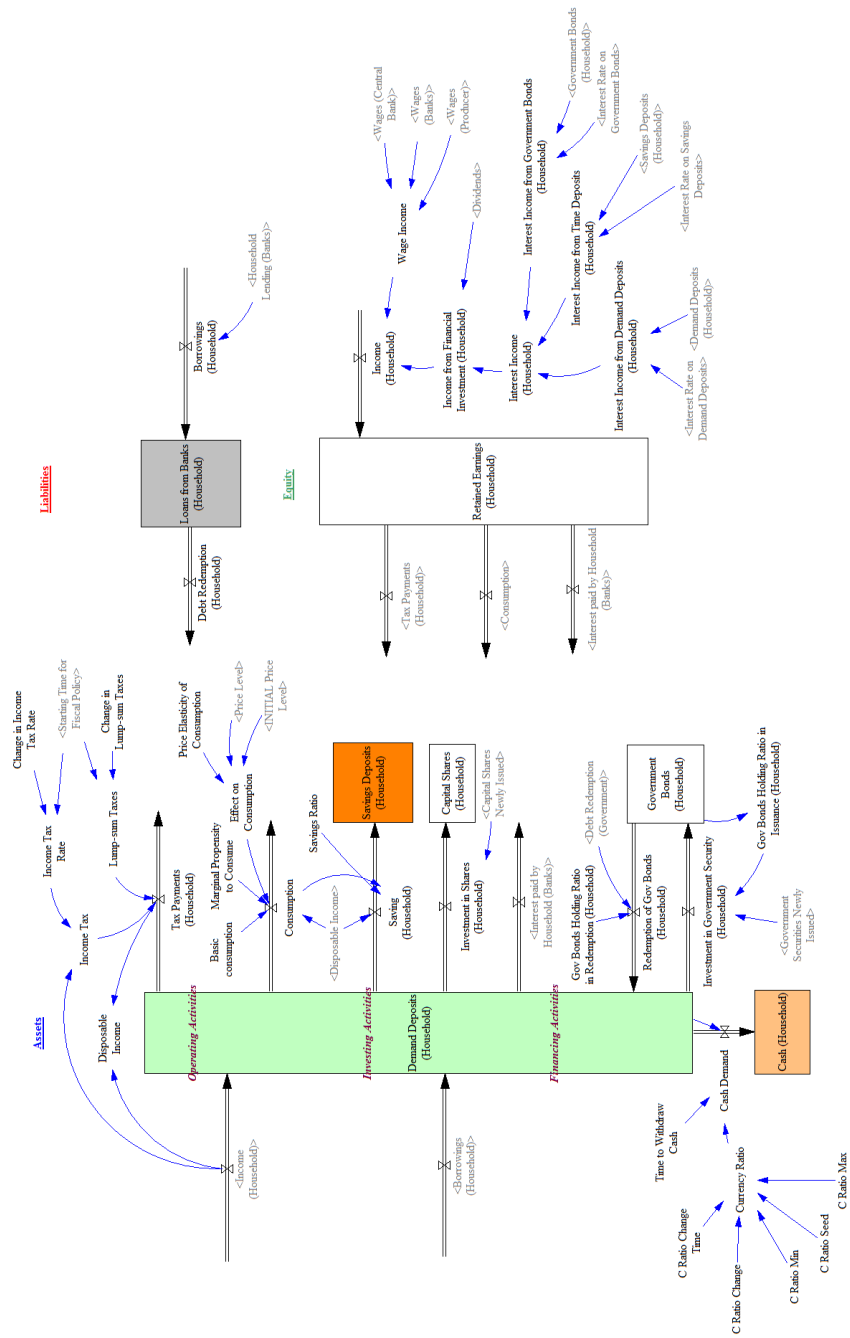


Figure 6: Transactions of Households

- 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 8, some of which are summarized below.

- Banks meet the cash demand from households sector. Banks keep deposits from 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 (*a fractional banking system*).
- From their own funds, banks invest in newly issued government bonds (primary market), against which interests are paid by the government through government deposits held at the central bank.
- Loans are made to producers by deposit creation out of nothing and 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**

In the complete macroeconomic model of stock approach, central bank plays a crucial role of providing base money that is used for payments of taxes and settlements of transactions among households and producers sector. The source of assets against which base money is issued is confined to government bonds in the current model. In short, base money is issued against debts by the government.

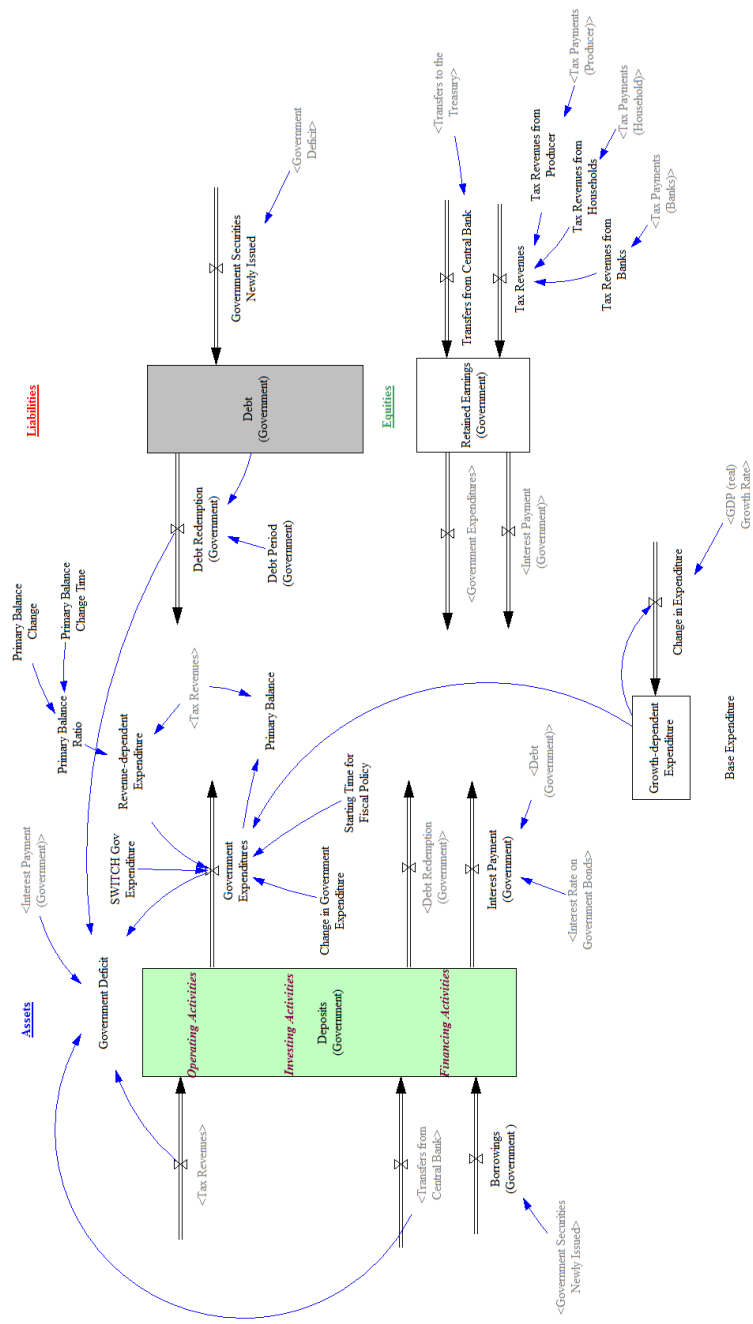


Figure 7: Transactions of the Government

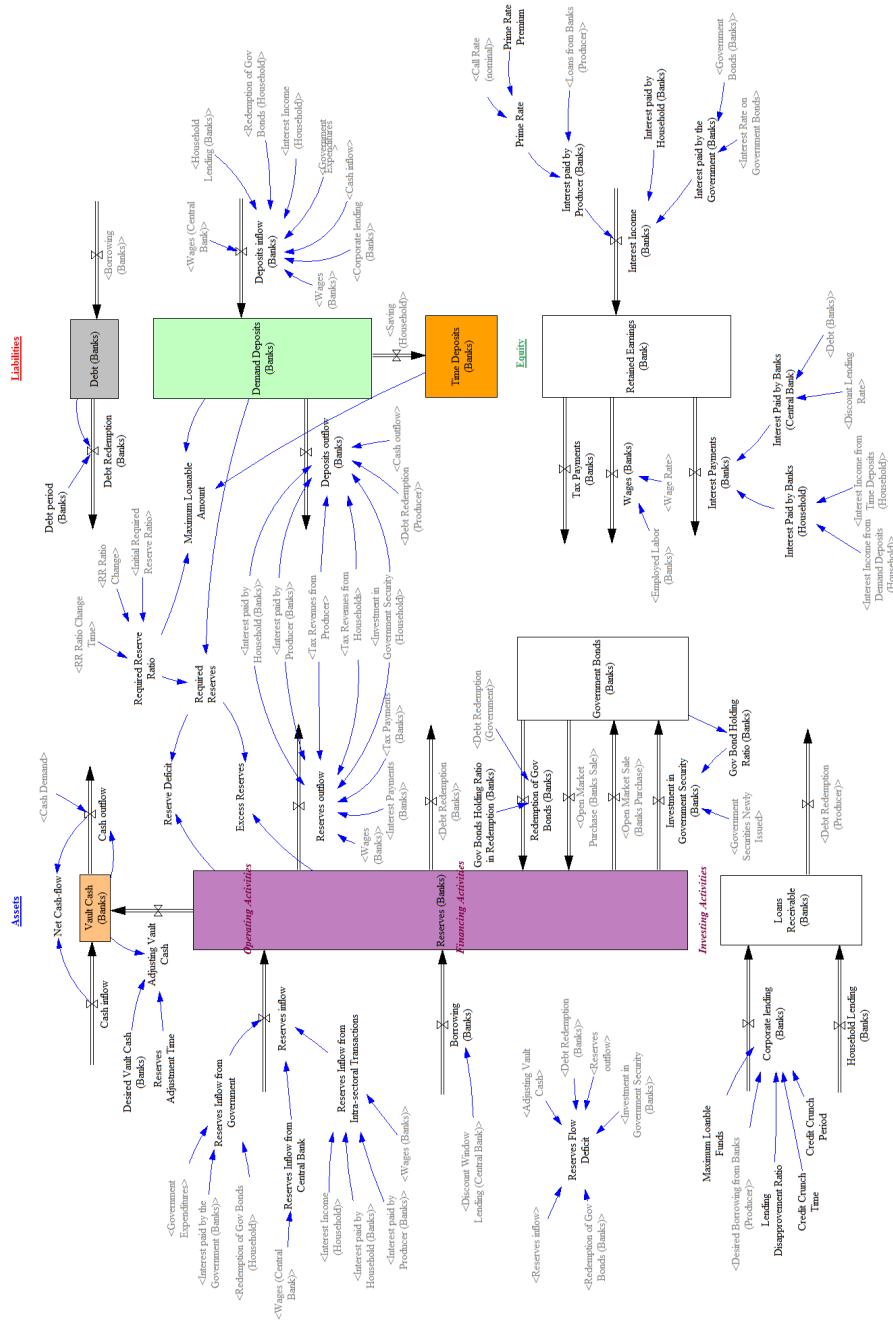


Figure 8: Transactions of Banks



In the stock approach model, central bank can directly affect the amount of base money through market operations, thereby affecting supply and demand relationships of reserves. Specifically, this can be done through monetary policies such as a manipulation of required reserve ratio, open market operations as well as direct control of lending to banks (credit facility).

Some of the transactions of the central bank are summarized below as illustrated in Figure 9.

- Central bank conducts open market operations by purchasing or selling government bonds only from and to banks. Purchase operations increase supply of reserves while sales operation withdraw reserves from the aggregate banking system. With the introduction of our expanded interest rate determination, changes in market operations affects nominal call rate.
- Moreover, it can inject reserves by making discount loans to commercial banks if needed.
- Banks are required by law to reserve a certain amount of deposits with the central bank. By controlling this required reserve ratio, the central bank can also control the supply and demand relationships of reserves, which may affect prime lending rate by way of changes in call rate. Hence, the central bank cannot control the amount of money supply directly but can affect the supply of reserve through market operations, reserve ratio and direct lending to banks..

## 5.4 Flow of Reserves and Bank Deposits

Our model of stock approach can handle separate flows of reserves and bank deposits as done in the actual payment system today. Let us briefly examine how this is done in the model.

### Flow of Commercial Bank Deposits

For the sake of understanding how money and bank deposits flow in different ways in our model, let us first see how a consumption spending by household is recorded in the microeconomic-level, meaning that banks are not aggregated into one sector. We use an exemplary transaction of a certain goods between households (buyers) and producers (sellers) who have bank accounts at different banks.<sup>13</sup> The transaction is made through the transfer of bank deposits as illustrated in Tables 8 and 9. As a result, the amount of deposits in the household's bank decreased while that of producer's bank increased correspondingly.

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<sup>13</sup>This transaction can also be thought of as a transaction between household and producer sector in the model at an aggregate level.

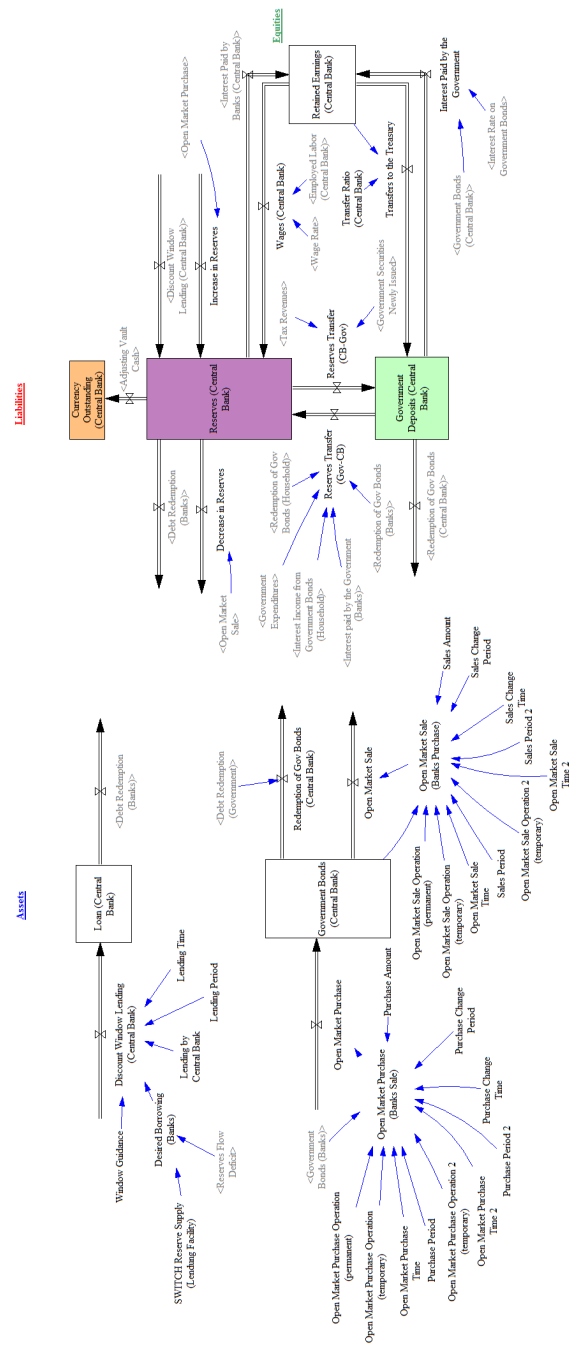


Figure 9: Transactions of Central Bank

Households		A Household's Bank	
Debit (Assets)	Credit (Assets)	Debit (Liability)	Credit (Assets)
Goods (+)	Deposits (-)	Deposits (-)	Reserves (-)

Table 8: Consumption from Household's (buyer) Perspective

Producers		A Producer's Bank	
Debit (Assets)	Credit (Assets)	Debit (Assets)	Credit (Liability)
Deposits (+)	Goods (-)	Reserves (+)	Deposits (+)

Table 9: Consumption from Producer's (seller) Perspective

### Flow of Central Bank Reserves

We have just discussed how the payment is made by the transfer of bank deposit.<sup>14</sup> Deposits are not money (legal tender) as we saw in section 2.1.3. How, then, banks can reach a settlement each other? Since central banks were institutionalized, settlements between commercial banks are done with central bank reserves which has payment finality. Table 10 extracts journal entries of bank's side from the previous Tables 8 and 9. As seen, the same consumption transaction made between households and producers is cleared out between two banks through central bank reserves.

A Household's Bank		A Producer's Bank	
Debit (Liability)	Credit (Asset)	Debit (Asset)	Credit (Liability)
Deposits (-)	Reserves (-)	Reserves (+)	Deposits (+)

Table 10: Settlement of deposit transfer by reserves

This separate but simultaneous flow of deposits and reserves originating from a single transaction is what is being incorporated into the model of the stock approach.

<sup>14</sup>The word "transfer" is used here as if deposits is moved from one bank to another. However, from Tables 5 (creation of deposits), 6 (destruction), and 8, 9 and 10 (payments by deposits), one could infer that bank deposits never leaves outside of the bank which created them in the first place.

## 5.5 Expansions and Contractions of Monetary Aggregates

Through the above-mentioned accounting mechanics, cash, bank deposits and central bank reserves held by different sectors dynamically change. This occurs as a result of chains of transactions made among five sectors in the model. However, there are limited number of transactions which lead to a creation and destruction of monetary aggregates. Specifically, only the central bank can increase or decrease  $M_0$  whereas money stock increase or decrease endogenously through interaction of bank lending and demand for loans by producers. Applying the quadruple-entry bookkeeping rule, it is explained below that base money ( $M_0$ ) and money stock have different mechanisms behind its expansion and contraction.<sup>15</sup>

### Expansion and Contraction of $M_0$

#### 5.5.1 When Does $M_0$ Increase?

$M_0$  or base money increases when:

- ① Central Bank buys bonds from financial institutions (banks in the model) that maintains reserve account at the central bank.
- ② Central Bank supplies reserves to banks. (Direct Lending Facility)

The case of transaction ① was examined already in Table 2. Table 11 illustrates the transaction case ② above.

Banks		A Central Bank	
Debit (Asset)	Credit (Liability)	Debit (Asset)	Credit (Liability)
Reserves (+)	Loans Payable (+)	Loans Receivable (+)	Reserves (+)

Table 11: Increase in Reserves through Direct Lending Facility

#### 5.5.2 When Does $M_0$ Decrease?

$M_0$  or base money decreases when:

- ③ The central bank sells government bonds back to banks through open market sale operations.
- ④ Banks repay direct loans from central bank.

<sup>15</sup>Not all transactions that leads to expansion or contraction of monetary aggregates in reality are listed here because they are not considered in the current model. For example, when commercial banks purchase bonds in the secondary market, this results in an corresponding increase in deposits, thus in money stock [7, 2014].

⑤ Government bonds held by central bank come due.

In the case of transaction ③ listed above, balance-sheets of banks and the central bank change according to the quadruple entries as shown in Table 12 below.

Banks		A Central Bank	
Debit (Asset)	Credit (Asset)	Debit (Liability)	Credit (Asset)
Gov. Bonds (+)	Reserves (-)	Reserves (-)	Gov. Bonds (-)

Table 12: Decrease in Reserves through Asset Sales

In the case of the transaction ④, balance-sheets of banks and a central bank change as illustrated in Table 13 shown below;

Banks		A Central Bank	
Debit (Liability)	Credit (Asset)	Debit (Liability)	Credit (Asset)
Loans Payable (-)	Reserves (-)	Reserves (-)	Loans Receivable (-)

Table 13: Decrease in Reserves when Banks repay loans from central bank

In the case of the transaction ⑤, balance-sheets of banks and a central bank change as illustrated in Table 14;

The Government		A Central Bank	
Debit (Liability)	Credit (Asset)	Debit (Liability)	Credit (Asset)
Gov. Debt (-)	Gov. Deposits (-)	Gov. Deposits (-)	Gov. Bonds (-)

Table 14: Decrease in Reserves when Gov. Bonds come due

As we have just examined, there are five specific transactions that cause base money to expand or contract in our model. Let us now examine cases for changes in money stock in the next section.

## Expansion and Contraction of Money Stock

### 5.5.3 When Does Money Stock Increase?

Money Stock increases when:

- ⑥ Loans are made by commercial banks to producers.
- ⑦ Banks invest in newly issued government bonds and the government spends that money back into the economy.

The case of ⑥ was examined already in Table 5. In the case of the transaction ⑦, there are two separate transactions involved. In the first part of the transaction where banks invest into government bonds, balance sheets of banks and the government changes, which are processed through reserve account at the central bank. This is illustrated in Table 15. For simplicity, we omit the implied changes within the liability side of central bank's balance sheet by this transaction.

Banks		The Government	
Debit (Asset)	Credit (Asset)	Debit (Asset)	Credit (Liability)
Gov. Bonds (+)	Reserves (-)	Gov. Deposits (+)	Gov. Debt (+)

Table 15: Banks invests in newly issued Gov Bonds

In the second part of transaction case ⑦ where the government spends newly borrowed money back in to the economy, balance sheets of banks and non-bank private sector (such as producers) change as illustrated in Table 16;

Producers		The government	
Debit (Asset)	Credit (Equity)	Debit (Equity)	Credit (Asset)
Deposits (+)	Retained Earnings (+)	Net Loss (-)	Deposits (-)

Table 16: The government spends newly borrowed money back into the economy  
1

As producers do not have reserves account at the central bank (separate flows of reserves and deposits), payments from the government to producers must go through central bank. Then, it eventually affects balance sheets of producers and banks as illustrated in Table 17, thereby increasing money stock at this point.

Producers		Banks	
Debit (Asset)	Credit (Equity)	Debit (Asset)	Credit (Liability)
Deposits (+)	Retained Earnings (+)	Reserves (+)	Deposits (+)

Table 17: The government spends newly borrowed money back into the economy  
2

One remark may be necessary for a case ⑦. Money stock does not increase just by the issuance of government bonds, which are invested by banks. The reason behind this can be checked by readers by considering implied changes in balance sheets after the government issued new bonds and bank invests their own funds but the government does not spend the acquired money back into the economy. In other words, transaction stops at the point shown in Table 15.

#### 5.5.4 When Does Money Stock Decrease?

Similarly, money stock decreases when:

- ⑧ Producers pay down their debt (bank loans).
- ⑨ When the government pays down its debt to banks (and banks only).<sup>16</sup>

The case for ⑧ was examined already in Table 6. Case ⑨ can be thought of as an opposite case of ⑦.

As we have examined above, there are four specific transactions that cause money stock to expand or contract in the model.

## 6 Model Equations

A core part of model equations are explicated in this section.<sup>17</sup>

### 6.1 Aggregate Supply

We begin by defining full capacity output level.

#### Production Function

In order to fully consider the role of capital  $K$  and employed labor  $L$ , the model adopts traditional Cobb-Douglas production function:

$$Y_{full} = F(K, L, A) = AK^\alpha L^\beta \quad (4)$$

<sup>16</sup>Note the difference here with the case of decrease in  $M_0$  when government bonds held by the central bank come due.

<sup>17</sup>As mentioned in section 5, the model structure is largely based on the original flow approach model presented in chapter 9 of Yamaguchi [15].

where  $A$  is a factor of technological change, and  $\alpha$  and  $\beta$  are exponents on capital and labor respectively. An economic output or GDP thus produced is defined as full capacity GDP.

By introducing the employed labor and total available labor force, it also becomes possible to define potential output or GDP as

$$Y_{potential} = F(K, LF, A) = AK^\alpha LF^\beta \quad (5)$$

where  $LF$  is the total amount of labor force which is defined as the sum of the employed and unemployed labor.

Let us assume that productivity due to technological progress grows exponentially such that

$$A = \bar{A}e^{\kappa t} \quad (6)$$

where  $\kappa$  is an annual increase rate of technological progress, which may be possible to be endogenously determined within the system. In the current model, however, this technological change  $\kappa$  is treated as an exogenous parameter of 0.003. Following the method by Nathan Forrester [4], let us normalize this production function with the initial potential GDP at  $t = 0$ :

$$\bar{Y}_{potential} = F(\bar{K}, \bar{L}F, \bar{A}) = \bar{A}\bar{K}^\alpha \bar{L}F^\beta \quad (\text{Initial Potential Output}) \quad (7)$$

Then, we have

$$Y_{full} = e^{\kappa t} \bar{Y}_{potential} \left( \frac{K}{\bar{K}} \right)^\alpha \left( \frac{L}{\bar{L}F} \right)^\beta \quad (8)$$

### Profits after Taxes

Now, before we define the investment function, let us first define profits after tax. In the model, three types of taxes are levied: tax on production (excise tax), corporate tax and income tax. The former two taxes are paid by producers (Figure 5), while income tax, consisting of lump-sum tax and a proportional part of income tax, is paid by households (Figure 6). With these into consideration, profits after tax  $\Pi$  are now defined as

$$\Pi = ((1 - t_e)PY_{full} - (i_L + \delta)P_K K - wL)(1 - t_c) \quad (9)$$

where  $t_e$  is an excise tax rate,  $t_c$  is a corporate profit tax rate,  $i_L$  is a nominal (prime) lending rate,  $\delta$  is a depreciation rate, and  $w$  is a nominal wage rate.

One remark may be appropriate for the definition of capital cost  $i_L P_K K$ . The amount of capital against which interests are paid are the amount of debt outstanding by producers (which is the same as the outstanding loans borrowed from banks) in the actual model. At an abstract theoretical level shown above, however, it is regarded as the same as the book value of capital from which depreciation is deducted. Our model based on the principles of accounting system dynamics enables us to distinguish these two. Specifically, capital cost (= interest paid by producers) are calculated in the model as

$$i_L P_K K \approx \text{Prime Rate} \cdot \text{Loans Payable}_{Producers} \quad (10)$$



## 6.2 Aggregate Demand

Let us define an aggregate demand next. Our hypothetical economy assumes a closed economy. Accordingly, an aggregate demand consists of household's (final) consumption spending ( $C$ ), capital investment by producers ( $I$ ), and the government expenditure ( $G$ ).

Hence, aggregate demand denoted as  $AD$  is defined as

$$AD = C + I + G \quad (11)$$

### Consumption Function

In our model, an aggregate household sector is assumed to follow consumption behavior as in the conventional Keynesian consumption function. Specifically, it is assumed to consist of two parts; fixed amount of consumption (basic consumption) and variable part of consumption spending. Then, it is further assumed that household consumption spending is affected by the price level. Specifically, marginal propensity to consume is now assumed to be dependent on a relative price elasticity of consumption such that

$$c(P) = \frac{1}{\left(\frac{P}{\bar{P}}\right)^e} \quad (12)$$

where  $\bar{P}$  is an initial price level and  $e$  is a relative price elasticity of consumption. In other words, marginal propensity to consume gets smaller as the current price level goes up relative to its initial level. It is called effect of price on consumption in the Figure 6.

Accordingly, the revised consumption function becomes

$$C(P) = C_0 + c(P)Y_d \quad (13)$$

The consumption function thus defined has a feature of a downward-sloping demand function, similar to a demand curve of consumers at a microeconomic level.

### Capital Investment Function

As explained earlier, producers are assumed to maximize their profits by adjusting capital investment. The first order condition for profit maximization with respect to capital stock is calculated by partially differentiating profits  $\Pi$  with respect to capital as

$$\begin{aligned}
\left(\frac{1}{1-t_c}\right) \frac{\partial \Pi}{\partial K} &= \alpha(1-t_e)Pe^{\kappa t} \left(\frac{\bar{Y}_{full}}{\bar{K}}\right) \left(\frac{K}{\bar{K}}\right)^{\alpha-1} \left(\frac{L}{\bar{L}}\right)^\beta - (i_L + \delta)P_K \\
&= \frac{\alpha(1-t_e)Pe^{\kappa t} \left(\frac{\bar{Y}_{full}}{\bar{K}}\right) \left(\frac{K}{\bar{K}}\right)^\alpha \left(\frac{L}{\bar{L}}\right)^\beta}{\frac{K}{\bar{K}}} - (i_L + \delta)P_K \\
&= \frac{\alpha(1-t_e)PY_{full}}{K} - (i_L + \delta)P_K \\
&= 0
\end{aligned} \tag{14}$$

Hence, the demand function for capital is obtained as

$$K = \frac{\alpha(1-t_e)PY_{full}}{(i_L + \delta)P_K} \tag{15}$$

At a macroeconomic level of a single commodity, price of output  $P$  is treated as the same as the price of capital stock  $P_K$ . Hence, a desired level of capital stock  $K^*$  could be approximately calculated by desired output  $Y^*$  as

$$K^*(i_L) = \frac{\alpha(1-t_e)Y^*}{i_L + \delta} \tag{16}$$

In our model desired output  $Y^*$  is represented by the level variable: Aggregate Demand Forecasting (Long-run) as illustrated in Figure 10 (see also [4]).

The amount of desired investment is now obtained as the difference between desired and actual capital stock such that

$$I(i_L) = \frac{K^*(i_L) - K}{\text{Time to Adjust Capital}} + \delta K \tag{17}$$

Furthermore, let us define desired capital-output ratio as follows:

$$\theta^*(i_L) = \frac{K^*}{Y^*} = \frac{\alpha(1-t_e)}{i_L + \delta} \tag{18}$$

### Government Expenditure

In the model, a simple approach is employed to determine the government expenditure. First approach is to assume that government expenditures are dependent on the tax revenues, which are endogenously determined by the size of output, income level (wage rate), tax rates and so on.

Accordingly, the government expenditure becomes a function of tax revenues  $T$ :

$$G = \mu \cdot T \tag{19}$$

where  $\mu$  is a ratio between government expenditures and tax revenues, called here a primary balance ratio. When  $\mu = 1$ , we have a so-called balanced budget,

while if  $\mu > 1$ , we have budget deficit, and vice versa. With the introduction of the government expenditures determined this way, all exogenously determined variables such as  $T, I$ , and  $G$  are now determined within the macroeconomic system.

Figure 10 shows stock and flow diagram of the determination of real GDP and capital formation.

### 6.3 Interest Rate Determination

Our stock approach model introduces an expanded version of interest determination process based on supply-demand relationship of central bank reserves. This enables us to incorporate a transmission mechanism of monetary policy through changes in the supply of reserves by open market operations as implemented by central banks.

#### 6.3.1 Call Rate (Money Market Rate)

The term "Call Rate", as is called by the Bank of Japan and the market participants, is a generic name used for interest rates applied on inter-bank money market. Under the fractional reserve banking system, commercial banks are facing with demand for reserves to meet the legal requirement. In normal times, there are mainly 3 types of demand that affects demand for reserves by banks: 1. Transaction demand due to deposit transfers instructed by depositors, 2. Reserve requirement demand, and 3. Demand for central bank notes in case of cash withdrawal by depositors. In our macroeconomic model where banks are assumed to be an aggregate sector, call rate  $i_R$  is a conceptual representation of inter-bank (wholesale) funding rate that is determined in the money market as follows:

$$\frac{di_R}{dt} = \psi(R^* - R^s) \quad (20)$$

where  $R^*$  denotes demand for reserves, while  $R^s$  indicates reserves supply. Let us define call rate equation more specifically as follows:

$$\frac{di_R}{dt} = \frac{i_R^* - i_R}{\text{Adjustment Time}} \quad (21)$$

where  $i_R^*$  is a desired call rate. Desired call rate is in turn determined by

$$i_R^* = i_R \cdot \frac{1}{\left(\frac{R_{Banks}}{RR}\right)^e} \quad (22)$$

where  $e$  is an elasticity of call rate. Hence, equation (21) describes an adjustment process of the current call rate  $i_R$  towards the desired rate, which in turn is determined by the supply demand ratio of central bank reserves. The supply-demand relationship of reserves (called here "Reserves Tightness") is expressed by a ratio defined as follows:

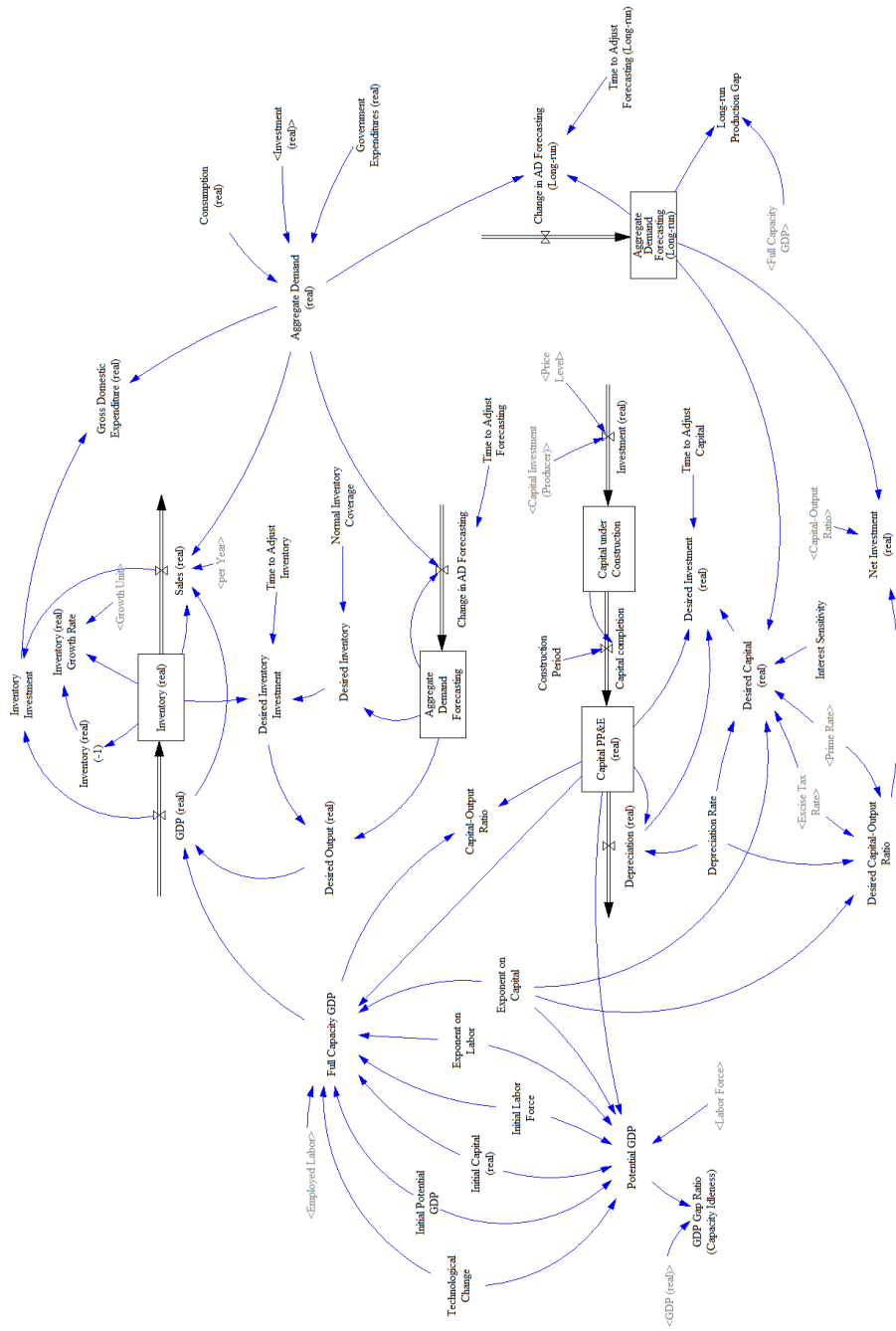


Figure 10: Determination of GDP and Capital Formation

$$\text{Reserves Tightness} = \frac{\text{Reserves}_{Banks}}{\text{Required Reserves}} = \frac{R_{Banks}}{RR} \quad (23)$$

$R_{Banks}$  is the total supply of reserves held by banks, which are held by reserves account on the liability side of the central bank's balance sheet in the Figure 9.

Required Reserves, on the other hand, is determined by

$$\text{Required Reserves} = \epsilon \cdot \text{Deposits}_{Banks} \quad (24)$$

where  $\epsilon$  is a required reserve ratio, which is assumed to be 0.02 or 2% under the current model. In this way, desired call rate  $i_R^*$  is determined according to how much central bank reserves are available for banking sector, which are affected by various macroeconomic transactions in the model, relative to required reserves, which is dynamically determined by the above equation (24).

### 6.3.2 Five Types of Nominal Interest Rates

In our current analysis, call rate  $i_R$  is assumed to be a basis of all other interest rates applied in the economy. For the sake of simplicity, these interest rates are assumed to move in lockstep with call rate. There are five different interest rates in the model, all of which are nominal rates.

1. Call Rate denoted as  $i_R$ .
2. Interest Rate on Demand Deposit denoted as  $i_D$ .
3. Interest Rate on Time Deposit (Saving Deposit) denoted as  $i_S$ .
4. Interest Rate on Government Bonds denoted as  $i_G$ .
5. Prime Lending Rate denoted as  $i_L$ .

These interest rates are determined by adding constant margins to the call rate such that

$$i_L = i_R + m_L \quad (25)$$

where  $m_L$  is a margin on (prime) lending rate added upon call rate. In the current version of the model, each interest rate has different margins, whose relationships are set such that

$$m_D < m_L < m_S < m_G \quad (26)$$

This means that five different interest rates incorporated in our generic model hold the following relationship throughout the whole simulation period.

$$i_D < i_R < i_L < i_S < i_G \quad (27)$$

The upper part of Figure 11 illustrates the determination processes of these nominal interest rates.

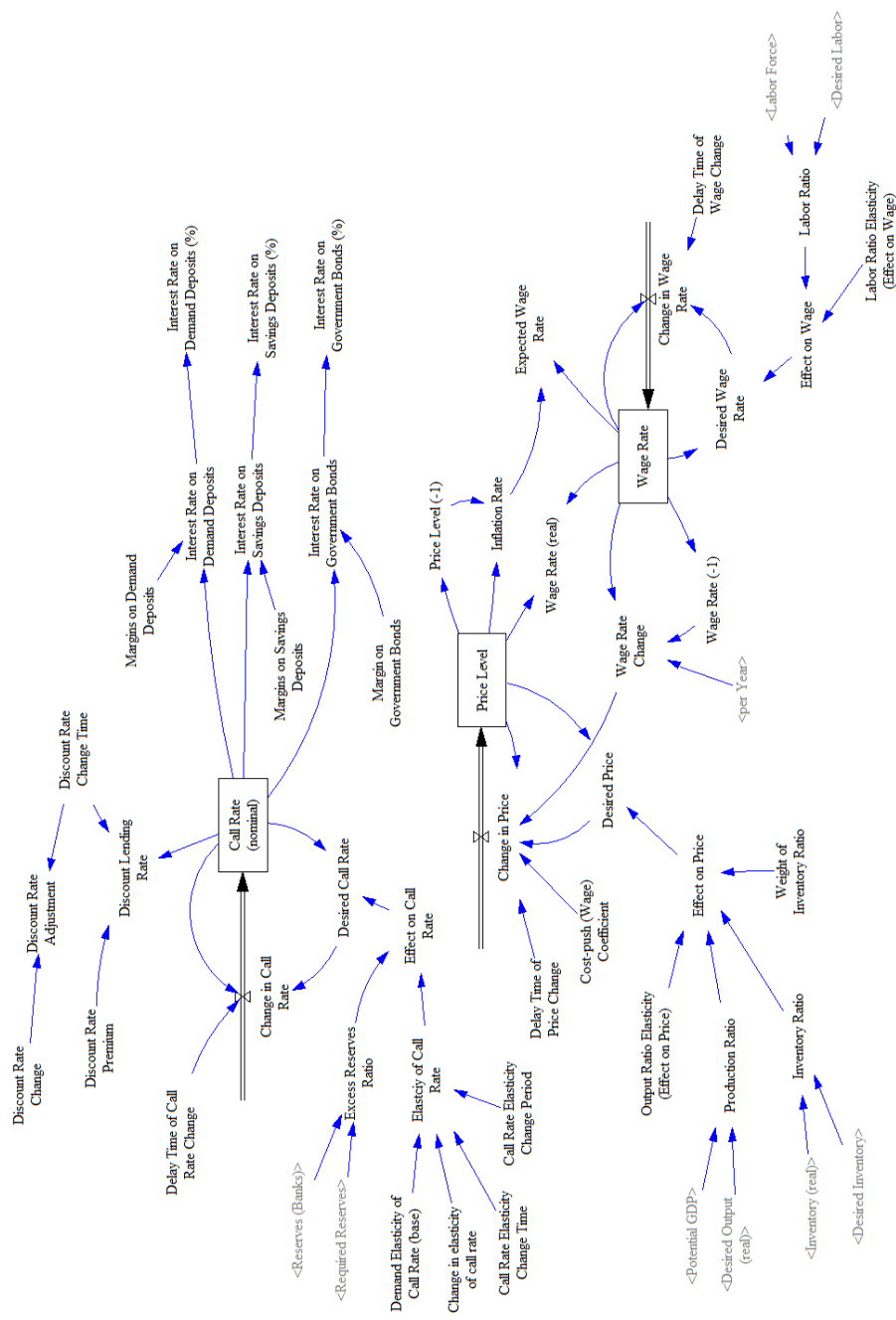


Figure 11: Interest Rates, Price and Wage Rate

## 6.4 Employment

As in the determination of capital investment, producers are assumed to adjust its labor force in order for maximizing their profits. First order condition for profit maximization with respect to labor is calculated as follows:

$$\begin{aligned}
 \left(\frac{1}{1-t_c}\right) \frac{\partial \Pi}{\partial L} &= \beta(1-t_e)Pe^{\kappa t} \left(\frac{\bar{Y}_{full}}{\bar{L}}\right) \left(\frac{K}{\bar{K}}\right)^\alpha \left(\frac{L}{\bar{L}}\right)^{\beta-1} - w \\
 &= \frac{\beta(1-t_e)Pe^{\kappa t} \left(\frac{\bar{Y}_{full}}{\bar{L}}\right) \left(\frac{K}{\bar{K}}\right)^\alpha \left(\frac{L}{\bar{L}}\right)^\beta}{\frac{L}{\bar{L}}} - w \\
 &= \frac{\beta(1-t_e)PY_{full}}{L} - w \\
 &= 0
 \end{aligned} \tag{28}$$

Demand for labor is thus obtained as

$$L^d = \frac{\beta(1-t_e)PY_{full}}{w}. \tag{29}$$

Specifically, it is a decreasing function of real wage rate  $w_R = w/P$ .

From this demand function for labor, desired level of labor  $L^*$  could be approximately obtained by desired output  $Y^*$  and expected wage rate  $w^e$  as

$$L^*(Y^*, w^e) = \frac{\beta(1-t_e)PY^*}{w^e} \tag{30}$$

The expected wage rate is assumed to be determined as

$$w^e = w(1 + \text{inflation rate}) \tag{31}$$

The determination of the wage rate will be discussed in the following section.

Net employment decision is now made according to the difference between desired and actual amount of labor such that

$$E(Y^*, w^e) = \frac{L^*(Y^*, w^e) - L}{\text{Time to Adjust Labor}} \tag{32}$$

Net employment thus defined has a downward-sloping shape such that

$$\frac{\partial E}{\partial w^e} = -\frac{\beta(1-t_e)Y^*}{\text{Time to Adjust Labor}} \frac{1}{(w^e)^2} < 0. \tag{33}$$

The amount of wages to be paid by producers is determined by

$$W = wL \tag{34}$$

as illustrated in Figure 5.

With the above first-order conditions (equation (15) and (29)), profits after tax are now rewritten as

$$\begin{aligned}
\Pi &= ((1 - t_e)PY_{full} - (i_L + \delta)P_K K - wL)(1 - t_c) \\
&= ((1 - t_e)PY_{full} - \alpha(1 - t_e)PY_{full} - \beta(1 - t_e)PY_{full})(1 - t_c) \\
&= (1 - t_e)(1 - t_c)(1 - \alpha - \beta)PY_{full}
\end{aligned} \tag{35}$$

Hence, if constant returns to scale is assumed, that is  $\alpha + \beta = 1$ , as is often done, then no profits after tax are made available, out of which dividends have to be paid to shareholders. Accordingly, a diminishing returns to scale is assumed in our model; that is,  $\alpha = 0.4$  and  $\beta = 0.5$  so that  $\alpha + \beta < 1$ .

## 6.5 Population and Labor Market

### Labor Market and Wage Rate Adjustment

So far labor demand is assumed to be fully met as the equation (32) indicates. To determine the real wage rate in the labor market, it is necessary to introduce the availability of labor supply, and the population dynamics of the economy by which labor supply is constrained.

In this macroeconomic model, population dynamics is modeled according to the World3 model<sup>18</sup>. It consists of four cohorts of age groups, and two population cohorts between age 15 to 44 and 45 to 64, which are considered to be a productive population cohort. The productive population cohort is further broken down into five different subgroups by category: high school, college education, voluntary employed, employed labor, and unemployed labor, as illustrated in Figure 12. Employed and unemployed labor constitutes a total labor force, by which potential GDP is calculated together with the amount of capital as defined earlier.

Nominal wage rate is now determined in the labor market as follows:

$$\frac{dw}{dt} = \phi(L^* - L^s) \tag{36}$$

where  $L^*$  denotes demand for desired labor, while  $L^s$  indicates supply of labor forces. Labor demand (and net employment) is in return determined by a real wage rate as in the equation (29).

Let us further specify the wage rate equation, as in the interest rate and price equations, as follows:

$$\frac{dw}{dt} = \frac{w^* - w}{\text{Adjustment Time}} \tag{37}$$

where the desired wage rate  $w^*$  is obtained as

$$w^* = \frac{w}{\left(\frac{L^s}{L^*}\right)^e} \tag{38}$$

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<sup>18</sup>Vensim version of the World3 model is provided in the vendor's sample models by Ventana Systems, Inc.



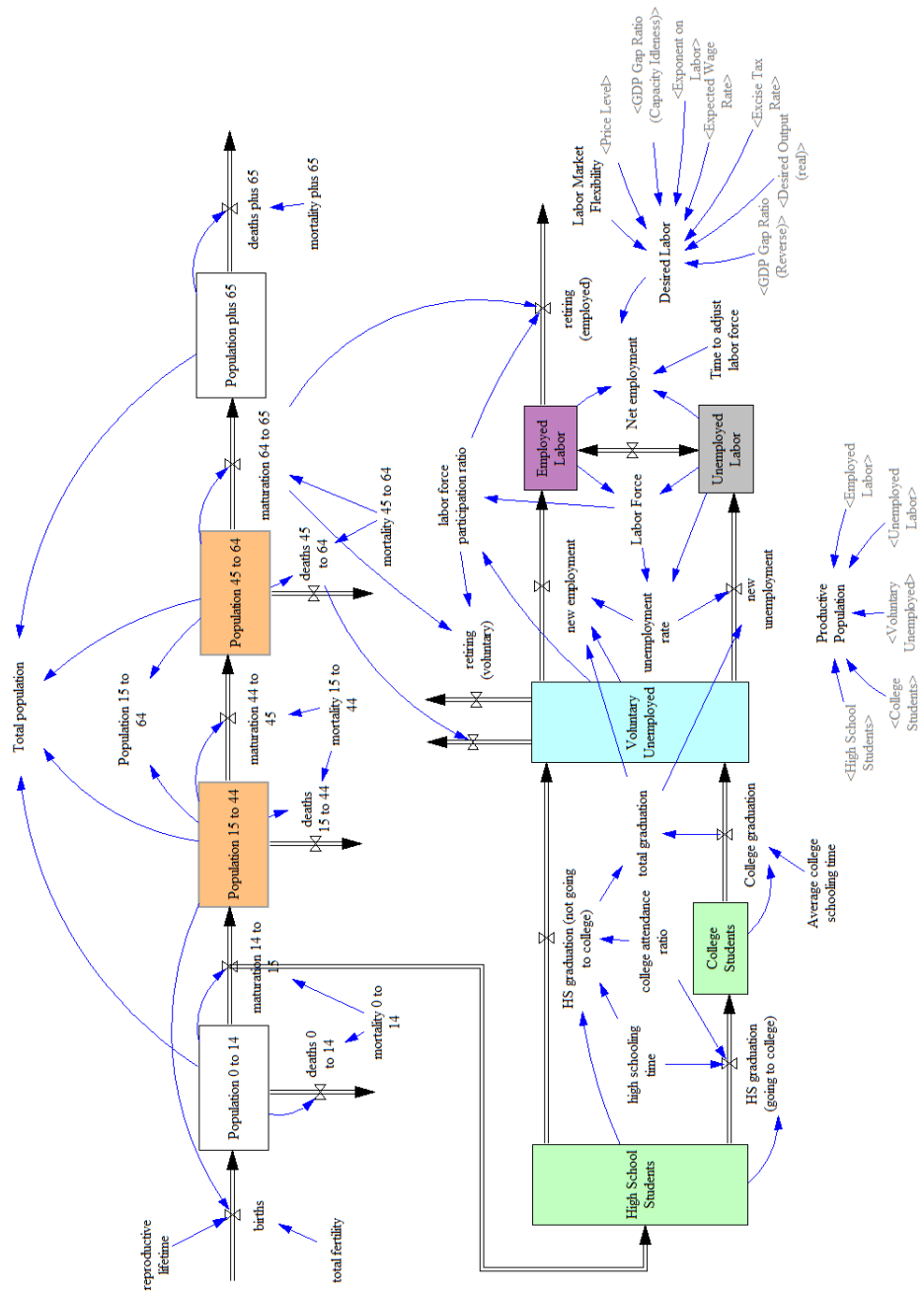


Figure 12: Population Dynamics and Labor Market

where  $e$  is a labor ratio elasticity.

These features are reflected in Figure 11.

## Price Adjustment by Demand-pull Force

Price level is assumed to change in the model as follows:

$$\frac{dP}{dt} = \frac{P^* - P}{\text{DelayTime}} \quad (39)$$

where  $P^*$  is desired price,  $P$  is the current level of price, adjusted by delay time of price change. The desired price  $P^*$  is defined in the same way as done in the flow approach model originally developed by Yamaguchi [14, 2006], where it is assumed to reflect the gap between potential GDP and desired output  $Y^D$  such that

$$P^* = \frac{P}{\left( (1 - \omega) \frac{Y_{potential}}{Y^D} + \omega \frac{I_{inv}}{I_{inv}^*} \right)^e} \quad (40)$$

where  $\omega, 0 \leq \omega \leq 1$ , is a weight between production and inventory ratios, and  $e$  is an elasticity called output ratio elasticity as shown in the Figure 11.

Accordingly, price  $P$  is assumed to be adjusted by the demand-pull forces generated by discrepancies between desired aggregate demand and potential GDP, and between inventory gap such that

$$\frac{dP}{dt} = \Psi(Y^D - Y_{potential}, I_{inv}^* - I_{inv}). \quad (41)$$

With the introduction of wage determination in equation (37), it now becomes possible to add cost-push forces factor to the price adjustment process. This cost-push force is represented by a change in the nominal wage rate such that

$$w_g = \frac{d \log(w)}{dt} \quad (42)$$

Hence, the price adjustment process is now influenced by demand-pull and cost-push forces such that

$$\frac{dP}{dt} = \Psi_1(Y^D - Y_{potential}, I_{inv}^* - I_{inv}) + \Psi_2(w_g) \quad (43)$$

The bottom part of the Figure 11 illustrates our revised model for adjustment processes of price and wage rate.

## 6.6 Selected Sector-Specific Transactions

### 6.6.1 Producers

#### Liquidity Deficit

Following the basic idea of applying the concept of cash-flow management to derive producer's demand for cash (liquidity) in the original flow approach model [15], net deposit-flow (NDF)<sup>19</sup> of producers sector is obtained similarly in our stock approach model. The steps for determining liquidity deficit shown below are illustrated in the bottom left corner in the Figure 5.

NDF of producers consists of three types based on corporate activities:

1. NDF from Operating Activities
2. NDF from Investing Activities
3. NDF from Financing Activities

By summing these up, net deposit flow of producers is obtained as follows:

$$\text{NDF}_{Producers} = \text{NDF}_{operating} + \text{NDF}_{investing} + \text{NDF}_{financing} \quad (44)$$

Specifically, net deposit flow from operating activities is obtained as

$$\text{NDF}_{operating} = \text{Sales} - \text{Wages} - \text{Tax Payments} \quad (45)$$

and net deposit flow from investing activities is obtained as below:

$$\text{NDF}_{investing} = - \text{Capital Investment} \quad (46)$$

Similarly, net deposit flow from financing activities is obtained as follows

$$\begin{aligned} \text{NDF}_{financing} = & \text{Bank Borrowings} + \text{Newly Issued Shares} \\ & - (\text{Expenditures}_{Debt} + \text{Expenditures}_{Equity}) \end{aligned} \quad (47)$$

where  $\text{Expenditures}_{Debt}$  and  $\text{Expenditures}_{Equity}$  are defined as follows respectively:

$$\text{Expenditures}_{Debt} = \text{Debt Redemption} + i_p \cdot \text{Debt}_{Producers} \quad (48)$$

$$\text{Expenditures}_{Equity} = \text{Dividends} \quad (49)$$

---

<sup>19</sup>It is called cash flow management in the flow approach model. However, it becomes inconsistent to use the term "cash" under the stock approach models because almost all transactions are made with deposits. Moreover, cash and bank deposits (functional-money) are fundamentally different as we saw earlier in section 2.

Finally, since deposit inflow acquired by bank borrowings and issuance of new capital shares cannot be counted when calculating their needs for additional funds, liquidity deficit of producers is obtained by excluding them from equation (44) as follows:

$$\begin{aligned} \text{Liquidity Deficit} = & \text{NDF}_{operating} + \text{NDF}_{investing} \\ & - (\text{Expenditures}_{DebtFinance} + \text{Expenditures}_{EquityFinance}) \end{aligned} \quad (50)$$

When producers are in a state of liquidity deficit, the liquidity deficit thus defined results in a negative value. Hence, it is converted to a positive value with the following condition such that

$$\text{Desired Financing} = \text{MAX}(-\text{Liquidity Deficit}, 0) \quad (51)$$

### Desired Borrowing from Banks

Once the liquidity deficit is obtained this way, producers ask for bank borrowings according to the direct financing ratio defined as follows;

$$\text{Desired Borrowing} = \text{Desired Financing} \cdot (1 - \text{Direct Financing Ratio}) \quad (52)$$

In our model, direct financing ratio is treated as an exogenous parameter and is assumed to be 0; that is, producers do not issue additional capital shares.

### Repayment of Bank Loans

In the model, producers are assumed to repay its debt to banks within a certain fixed average period of time. Specifically, they repay debts as follows:

$$\text{Debt Repayment}_{Producers} = \frac{\text{Bank Loans}_{Producers}}{\text{Debt Period}_{Producers}} \quad (53)$$

where debt period is treated as an exogenous constant parameter in the model. This formulation means that the amount of debt repayment in a given period of time increases as their loans from banks increase. As discussed in section 5.5, repayments of bank loan itself directly leads to destruction of deposits in the model.

## 6.6.2 Banks

### Lendings

Our model applies stock approach of modeling bank lending discussed in section 3.3. Bank lending results in an increase in loans receivable (asset item) with the corresponding increase in the amount of demand deposits (liability item).

Specifically, bank lending is a function of desired borrowing, which in turn depends on numerous factors affecting their demand deposit (liquidity) explained above.

Accordingly, bank lending to producers (called here "Corporate Lending") is determined by

$$\text{Corporate Lending} = \text{MIN}(\text{Desired Borrowing}, \text{MLF}) \quad (54)$$

where MLF is maximum loanable funds. Maximum Loanable Funds (MLF) is determined as follows:

$$\text{MLF} = \frac{\frac{R_{\text{Banks}}}{\epsilon} - (D_d + D_s)}{\text{Lending Delay Time}} \quad (55)$$

where  $D_d$  is the sum of demand deposits held by producers and households,  $D_s$  is time deposits only held by households, both of which also appear on the liability side of the bank's balance sheet. Bank lending amount thus determined becomes the actual bank borrowing of producers such that

$$\text{Corporate Lending} = \text{Borrowings}_{\text{Producers}} \quad (56)$$

As discussed in the section 5.5, the bank lending transaction is one of the two transactions which leads to creation of new deposits in our model, thereby expanding money stock of the economy.

### 6.6.3 Government

#### Government Securities Newly Issued

Under the current monetary system of fractional reserve banking, central bank supply the majority of base money while commercial banks provide the majority of money stock. The government sector finances by issuing government securities to fill the gap between tax revenues and expenditures, namely by borrowing from private sectors including the central bank. In our model, the government borrows money according to government deficit as follows

$$\text{Securities Newly Issued}_{\text{Gov.}} = \text{Government Deficit} \quad (57)$$

#### Government Deficit

Government deficit (GD), which captures the difference between total revenues and total expenditures of the government, is obtained in our model as follows:

$$\begin{aligned} \text{GD} = & (G + \text{Debt Redemption}_{\text{Gov.}} + \text{Interest Payment}_{\text{Gov.}}) \\ & - T - \text{Transfer}_{\text{CB}} \end{aligned} \quad (58)$$

where the first part of the right argument is the total inflow of money and the latter part is the total outflow of money from the government. The amount of transfer paid by central bank  $\text{Transfer}_{CB}$  is defined below.

### Fiscal Deficit

Fiscal deficit, on the other hand, compares the deficit by excluding the amount of debt redemption from the previous government deficit as follows:

$$\text{Fiscal Deficit} = G + \text{Interest Payment}_{Gov.} - T \quad (59)$$

### Primary Balance

Primary balance compares tax revenues  $T$  and expenditures  $G$  as defined by

$$\text{Primary Balance} = T - G \quad (60)$$

As defined by equations (58) (59) and (60) above, the model is able to trace three different level of deficits in the government sector.

### Transfer from the Central Bank

As a result of open market operations, central bank holds government bonds on which interest is accrued. In many countries, central banks transfer a portion of interest income back to the government as a transfer to the treasury department. The current model incorporates this institutional reality and structure. Specifically, central bank is simply assumed to transfer a fixed portion of its retained earnings every year, which is determined by the following

$$\text{Transfer}_{CB} = \text{Retained Earnings}_{CB} \cdot \text{Transfer Ratio} \quad (61)$$

where transfer ratio is treated as an exogenous parameter in the model.

### Redemption of the Government Debt

In our model, government debt is assumed to be redeemed constantly such that

$$\text{Debt Redemption}_{Gov.} = \frac{\text{Debt}_{Gov.}}{\text{Debt Period}_{Gov.}} \quad (62)$$

where the government debt period is assumed to be a constant value of 10 years.

## 6.7 Causal Loop Diagram

System dynamics approach often utilizes causal loop diagram (CLD) as part of its analysis to study which system structure and feedback loop(s) is driving behaviors of the system under study. In CLD diagrams, arrows connect variables and denote causal influences among them. In our CLD shown in Figure

13, blue arrows indicate a positive causal relationship while red ones indicate the opposite relationship<sup>20</sup>. Arrows with double line dash crossing the arrow indicate existence of significant time delay in the causal influence, contributing to complex dynamic behaviors. A CLD below presents various feedback loops underlining our model.

Followings are the major (time) delays explicitly assumed in the model.

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

The CLD diagram is a qualitative summary of feedback effects assumed in the model.

## 7 Model Tests

Three different type of tests were applied to the model to examine its internal coherence and model behaviors.

### 7.1 Unit Consistency Test

We have performed a unit consistency test using the built-in algorithm of the Vensim program. The model clears unit consistency test for all equations in the model. The test increases awareness of modelers to formulate mathematical relationship grounded on realistic representation of real-world variables and logical consistency among them.

### 7.2 Balance Sheets Test

We have performed balance sheet tests and confirmed coherence of all balance sheets of all five sectors. Due to the rule of double entry bookkeeping and principles of accounting system dynamics modeling, the sum of asset items and the sum of all items of liability and equity items must be in balance fro all sectors at all times. Taking a case of Households sector, the following relationship holds

$$\text{Assets}_{Households} = \text{Liabilities}_{Households} + \text{Equities}_{Households} \quad (63)$$

This means that

$$\text{Assets}_{Households} - \text{Liabilities}_{Households} - \text{Equities}_{Households} = 0 \quad (64)$$

Balance sheet tests in our model applies the equation (64) for all five sectors. Figure 14 reports that all values are almost close to zero, clearing the test.

<sup>20</sup>If there is a blue arrow from variable X to Y, the reader can interpret it as: If X increases, then Y also increases above what it would have been otherwise if all else were equal. For detailed explanations and discussion on the proper usage of CLD, see chapter 5 of Sterman [10, 2000].

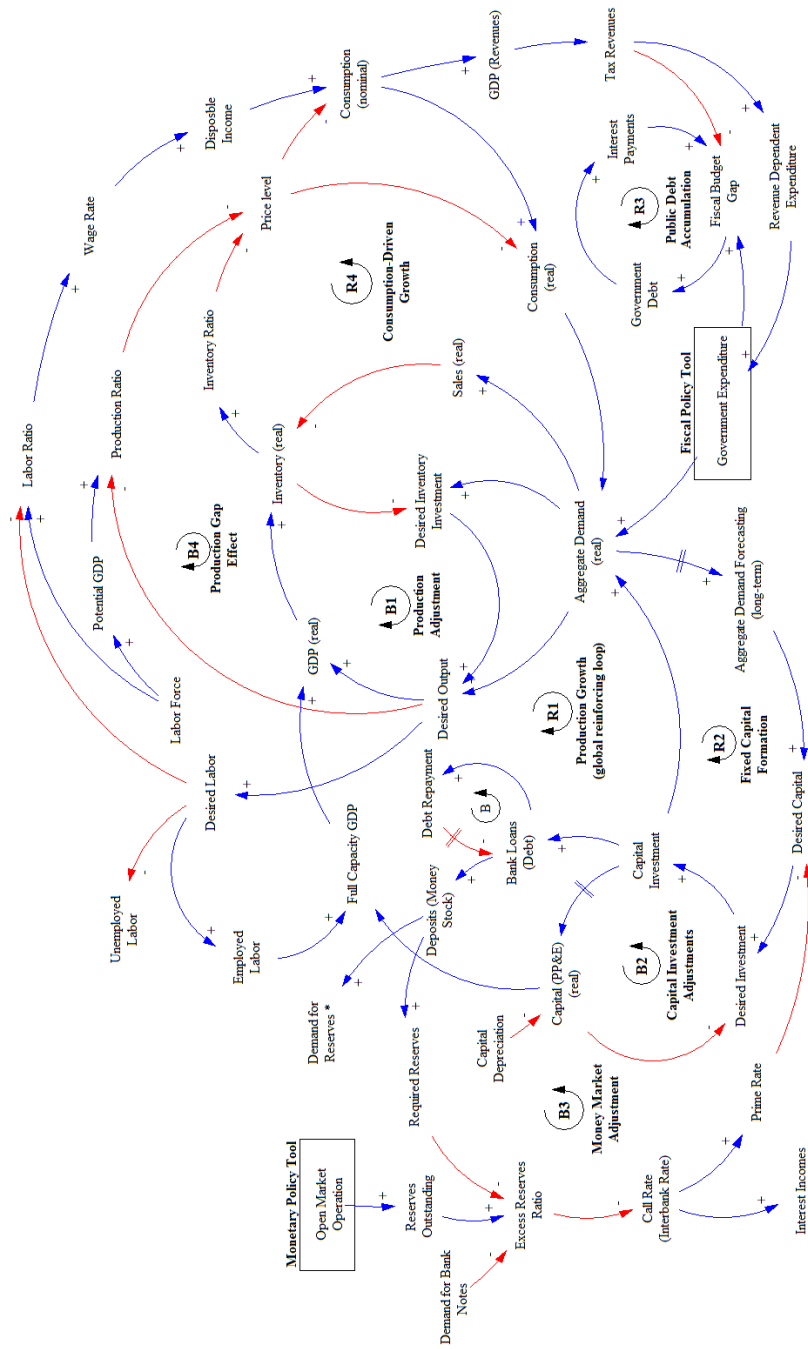


Figure 13: A Casual Loop Diagram of GDP Determination



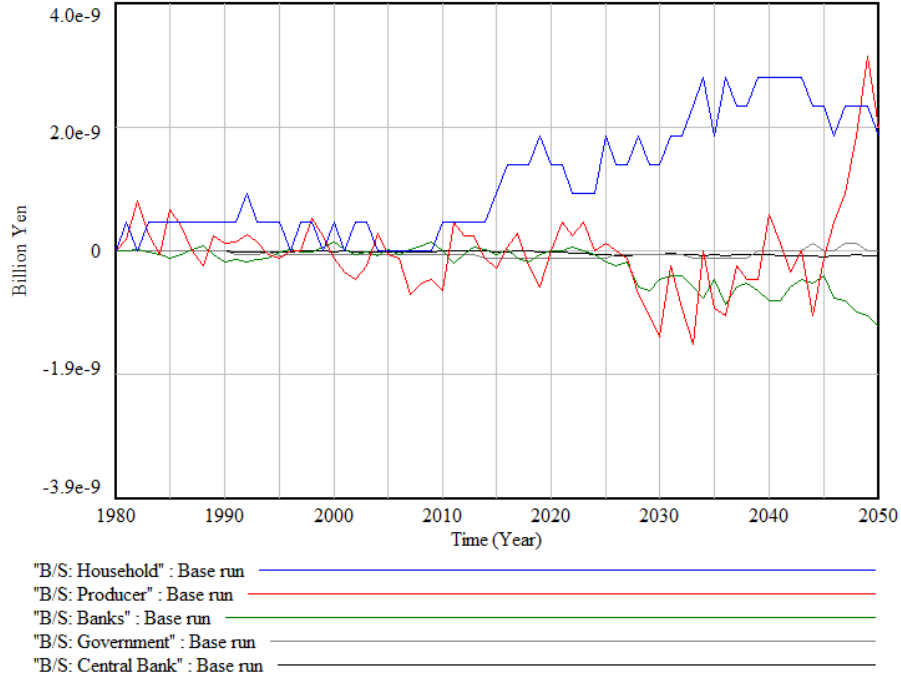


Figure 14: A clearance of Balance Sheet tests for all sectors

### 7.3 Flow of Funds Test

Flow of Funds (FF) tests make sure that all changes in the amount of a specific item (level variables) appearing on different side of the balance sheets across sectors caused by a certain transaction between two or three parties must always be kept recorded simultaneously and in a coherent way.

As an example let us take currency outstanding, which appears as a liability item of the central bank as shown in the Figure 9. Since it is assumed that household and banks hold cash as their assets, the following must be met throughout whole simulation period at a macroeconomic level such that

$$\text{Currency Outstanding}_{CB} = \text{Cash}_{Households} + \text{Vault Cash}_{Banks} \quad (65)$$

This means that

$$\text{Currency Outstanding}_{CB} - \text{Cash}_{Households} - \text{Vault Cash}_{Banks} = 0 \quad (66)$$

Flow of Funds tests in our model applies similar thinking as in the equation (66) to all financial items (level variables) in balance sheets. Figure 15 and 16 reports that the all values remain close to zero, clearing FF tests for all

financial transaction items incorporated in the model, given round-off errors that are negligible.

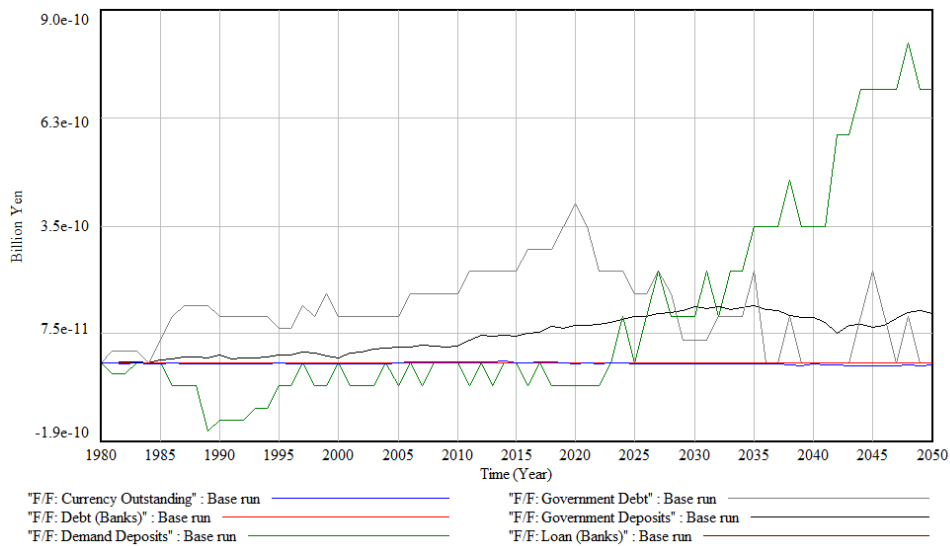


Figure 15: A clearance of Flow of Funds tests 1

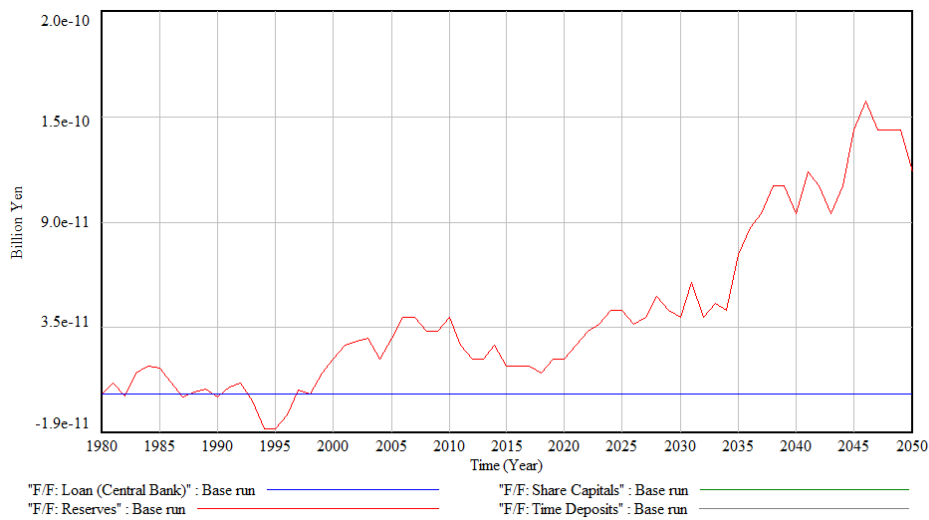


Figure 16: A clearance of Flow of Funds tests 2

It is in our understanding that clearances of balance sheet and flow of funds tests in our macroeconomic model increase an internal coherence of simulation

behaviors and applying the tests provides reality check to all quantitative models that incorporate financial structures.

## 8 Analysis of Base Run Behavior

Now that our ASD macroeconomic model of the stock approach is completed, we are in a position to analyze its behaviors. Reinforcing (R) and balancing (B) feedback effects are already summarized in causal loop diagram.

### 8.1 Equilibrium and Disequilibrium States

We begin by running a base run simulation ("base run"). Let us first define an *equilibrium state* when the following three levels of output and aggregate demand are met:

$$\text{Full Capacity GDP} = \text{Desired Output} = \text{Aggregate Demand} \quad (67)$$

If the economy is not in the equilibrium state or simply *disequilibrium*, then the actual GDP is determined by

$$\text{GDP (real)} = \text{MIN} (\text{Full Capacity GDP}, \text{Desired Output} ) \quad (68)$$

This reflects a constraint of production capacity on GDP whenever desired output exceeds full capacity GDP. Thus in disequilibrium states, GDP is determined by the amount of desired output which is the total output production sector wishes to produce to maximize their profit while leaving the capacity idle or laying off some of the workers.

Even though, full capacity GDP is attained, full employment may not be realized unless

$$\text{Potential GDP} = \text{Full Capacity GDP} \quad (69)$$

Does the equilibrium state, then, exist in the sense of full capacity GDP and full employment? In order to answer this question, let us define GDP gap as the difference between potential GDP and actual GDP, and its ratio to the potential GDP as

$$GDP_{gap} = \frac{Y - Y_{potential}}{Y_{potential}} \quad (70)$$

Accordingly, whenever the gap becomes negative, an economy is said to be out of equilibrium.<sup>21</sup>

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<sup>21</sup>Equilibrium defined here for our analysis is a different meaning of equilibrium used to indicate a equilibrium system state in system dynamics models where net flows of stock variables are zero.

## 8.2 Base Run (1980-2050)

For a unit of currency, Yen is chosen arbitrarily. Simulation is run for 70 years and the time boundary is set from 1980 to 2050.<sup>22</sup>

Our model begins with disequilibrium as shown by a blue line in Figure 17. Specifically, it attains equilibrium between a period from 1987 to 1994.

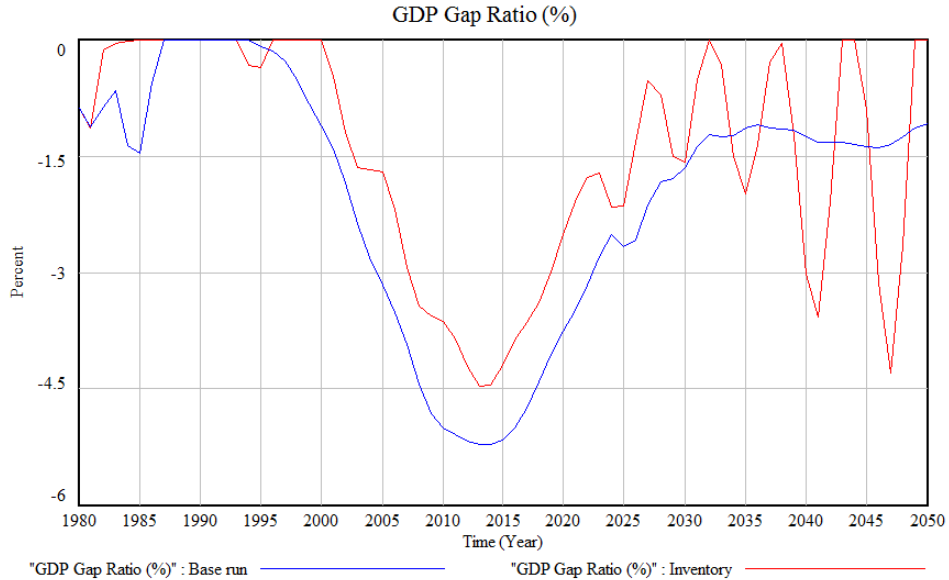


Figure 17: Economic Fluctuations amplified by Inventory Coverage

Figure 18 shows behaviors of nominal GDP (blue), real GDP (red), Aggregate Demand (real) (green), Full Capacity GDP (grey) and potential GDP (black). The reason why nominal GDP is higher than potential GDP (real) between 1986 and 2005 is due to inflation. This is confirmed by the higher inflation rate observed during the same period in Figure 23 as we discuss below. As we saw earlier, this diminishing rate of economic growth is largely caused by the diminishing returns to scale assumed in production function ( $\alpha + \beta < 1$ ) and the gradual decrease of productive labor force population assumed in the model as explained below. As a result, potential GDP (black line) reaches its peak level at year 2041 and records negative growth rate onwards. A wide GDP gap observed around a period of 2010-2014 shown by the blue line in Figure 17 begins to close after the year 2014. This is due to the recovery in the real GDP (red line) observed around the same period while growth of potential GDP is diminishing.

<sup>22</sup>The current model is used for an exploratory purpose. Therefore, simulation time does not correspond to historical time of any economy except the behaviors of population sub-model, which are explained in detail separately in the main text.

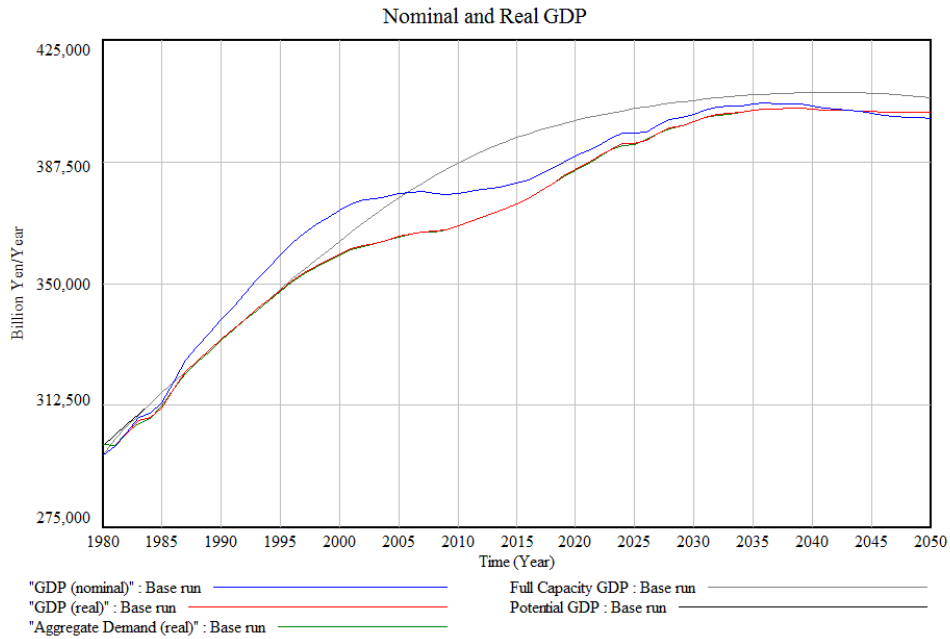


Figure 18: Behaviors of Real and Nominal GDP between 1980-2050

In the same Figure 18, a black line for potential GDP disappears after the year 1984 under the grey line of full capacity GDP. This is because the demand for labor exceeds that of supply and unemployed labor remains close to zero throughout the the base run simulation case. Particular assumptions made in the initial values and parameters around the population sub-model is discussed later. Let us next explore our base run scenario in more detail.

### Growth, Recession and Mild Recovery of GDP

Figure 18 depicts that both real and nominal GDP grow at a relatively higher rate during the early phase of simulation, reaching the peak growth rate of about 2% in year 1986. After the higher growth phase observed until the year 1990, growth rates of both real and nominal GDP gradually begin to diminish. At a year 2008 and 2009, the growth rate of nominal GDP records negative value of - 0.2 and - 0.1% respectively. Then, after experiencing years of low growth in demand and deflationary pressure created by the opposite force of demand-pull, an economic output gradually begins to recover led by a recovery in consumption spending. This self-propelling recovery from long-term recession observed in the base run case is driven primarily by the consumption-driven reinforcing feedback loop (R4).

Let us look into this long-term behavior of high growth, stagnation, recession and mild recovery in more detail below.

## Growth of Capital Investment

Figure 19 illustrates behaviors of nominal GDP and its components. As clearly observed in the figure, the growth of an economy at its early phase is supported by this stable increase in capital investment by production sector (R2), which is in turn supported by an enduring demand of consumption and government spending (R4) as illustrated in the same Figure 19.

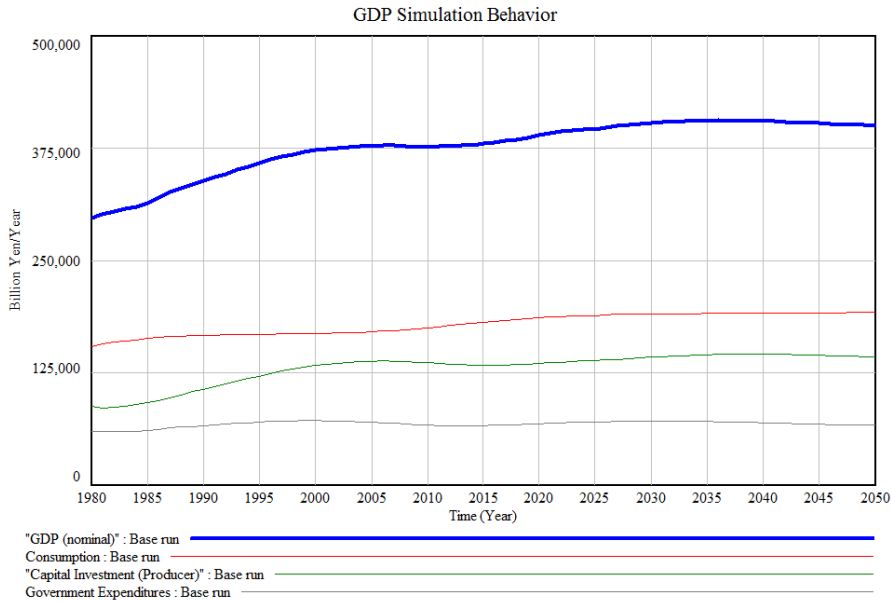


Figure 19: Behaviors of Nominal GDP and its components

The overall growth of an output is driven by the reinforcing feedback loop of production growth (R1) analyzed in causal loop diagram, which operates hand-in-hand with consumption-driven feed back loop (R4). However, aggregate demand begins to decrease slightly at around year 1990, which is caused by mild reduction in nominal consumption spending seen during high inflation period. This eventually causes capital investment to slow down (B1, B2 and B4).

## Accumulation of Government Debt

Under the base run scenario, government expenditure is assumed to be the same as tax revenues because primary balance ratio  $\mu$  is set to be at 1 in the equation (19), that is, a balanced budget assumption. This means that the government expenditure expands when tax revenues expands, and vice versa as observed by a grey line in the Figure 19.

Figure 20 below shows a behavior of government debt outstanding under this balanced budget condition. Surprisingly, the government debt continues to

increase even under the balanced budget assumption. This is because primary balance ratio compares a fiscal deficit between tax revenues less expenditures, excluding payments of debt redemption and interests accrued as in equation (60). Hence, as long as interest are accruing every year on debt outstanding, the simulation shows that achieving the perfect balanced budget in primary balance is an insufficient target for attaining long-term fiscal sustainability. As a matter of fact, we observe that the debt is growing at exponential rate. The rate of growth at the beginning may look relatively low, however, growth is driven by the reinforcing feedback loop of Public Debt Accumulation (R3) analyzed in the causal loop diagram. Clearly, the more the government waits, the higher their interest payments get, and less likeliness for fiscal reconstruction under such circumstances.

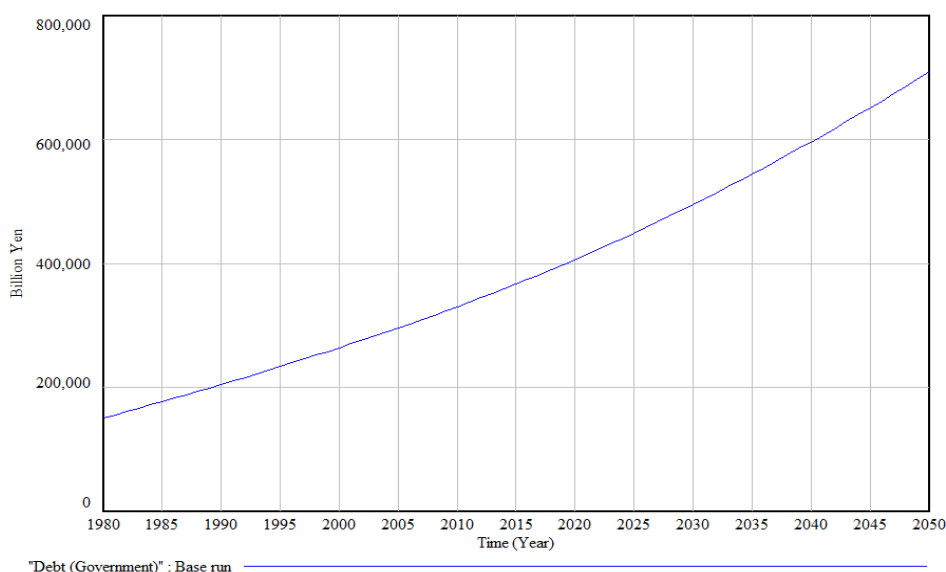


Figure 20: Exponential Growth of Government Debt Outstanding

### Expansion of Monetary Aggregates

The model captures currency outstanding, base money (interchangeably called  $M_0$ ),  $M_1$  and  $M_2$ . The difference between  $M_1$  and  $M_2$  defined in our model is whether time deposits of the households sector are included in calculating money stock or not.  $M_1$  consists of currency outstanding and demand deposits while  $M_2$  includes time deposits in addition to the components in  $M_1$ . Figure 21 reports behaviors of the three primary indicators, base money or  $M_0$  (blue),  $M_1$  (red) and  $M_2$  (green) together with major components such as reserves outstanding (grey), demand deposits of households (dark grey) and producers (brown). The amount of base money remains fairly stable while that of money

stock expands as economy grows. Under such a case, money multiplier does not remain constant and is unstable. Figure 22 shows behaviors of money multiplier for  $M_1$  (red) and  $M_2$  (green).

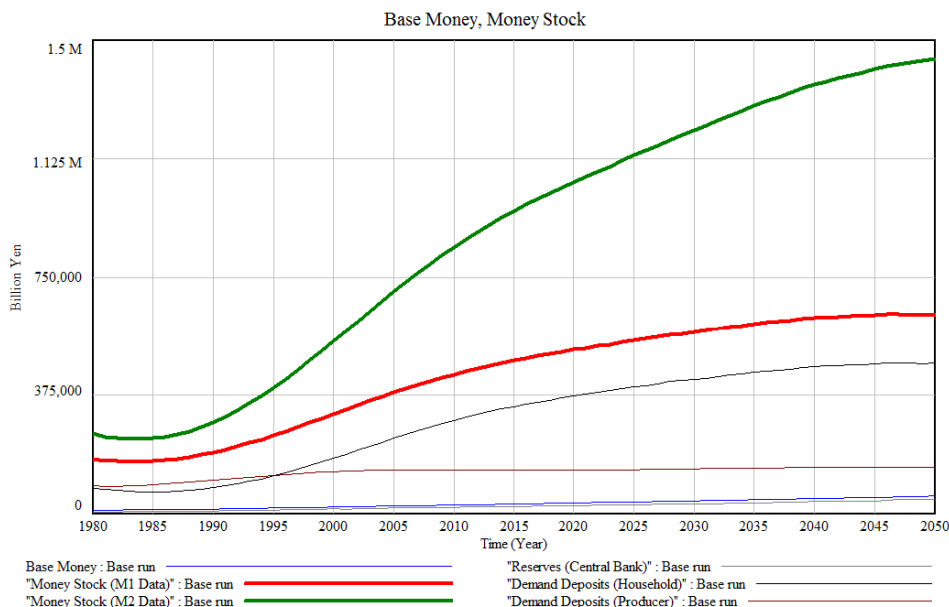


Figure 21: Variability of  $M_1$  and  $M_2$  under Stable  $M_0$

Base run simulation assumes the required reserve ratio to be constant at 2% for the whole simulation period. Under the growing economy, the need for money stock continuously increase. Increase in money stock under no additional increase in base money would impose gradual upward pressure on call rate. In our base run, therefore, central bank is assumed to constantly purchase a fraction of government bonds held by banks, thereby injecting reserves into an aggregate banking sector so that call rate continue to decrease so as to continuously stimulate capital investment. The decreasing call rate is show by a blue line in Figure 35 below.

### Inflation and Deflation

Price level is assumed to be affected by the demand pull-up or supply push-down forces in the model. As we saw earlier, the economy experiences growth supported by enduring demand at its early phase. This generates demand pull-up forces on price during the growth period. Figure 23 illustrates inflation period from 1980 until the end of 2002.

Driven primarily by the balancing feedback loop of Production Adjustment (B1) together with the effect of inflation on aggregate demand, economy's desired output gradually begins to grow at a diminishing rate. This leads to a peak



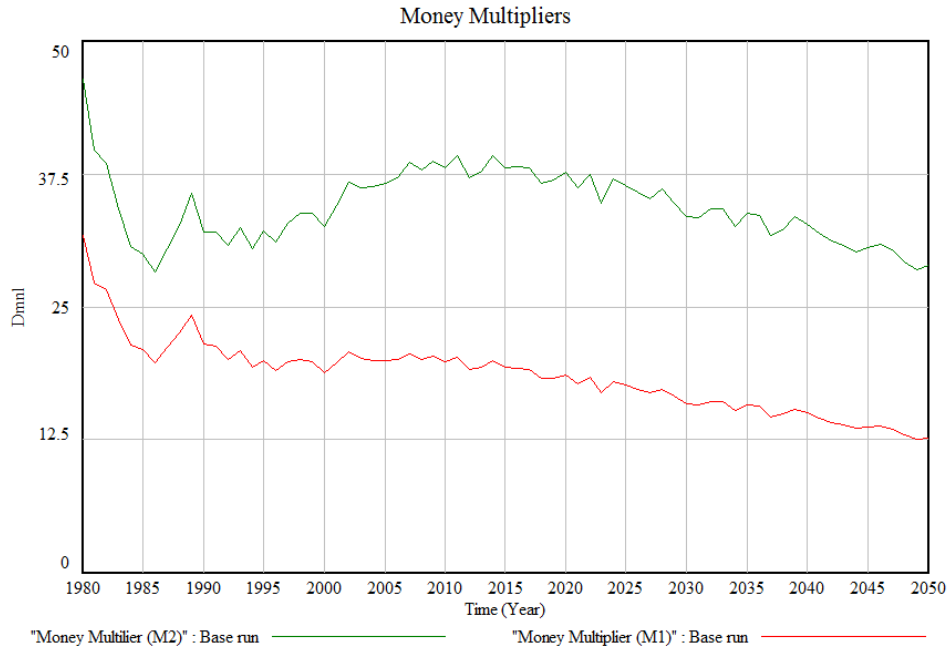


Figure 22: Behaviors of Money Multiplier for  $M_1$ ,  $M_2$

in growth rate of capital investment at 1988 as shown by Figure 24. From that year onwards, the growth rate in real capital investment begins to decrease. As the overall economy begins to be sluggish, macroeconomic growth that has been led by the global reinforcing loop of production growth (R1) starts to be dampened, and the balancing feedback loop of production adjustment (B1) and the capital investment adjustment (B2) begin to dominate the entire economy. An enduring dominance of the balancing feedback loops finally drive the economy into deflationary phase starting from 2003 as shown in the Figure 23. Then, the economy is shown to gain momentum led by an mild recovery in consumption spending starting at around year 2006 due to the effect of price level on nominal consumption spending.

### Decline of Productive Population

Though our objective of the current simulation analysis is not to replicate nor project actual growth path of any real-world economy, a modeling work must build upon realistic assumptions observed in historical behaviors of related system. Labor force plays significant role in determining the output over the long-term in our model. Therefore, we have assumed the population sector to represent historical demographic changes of Japanese population since 1980 up until 2013 in the current research. Specifically, initial values for level variables in pop-

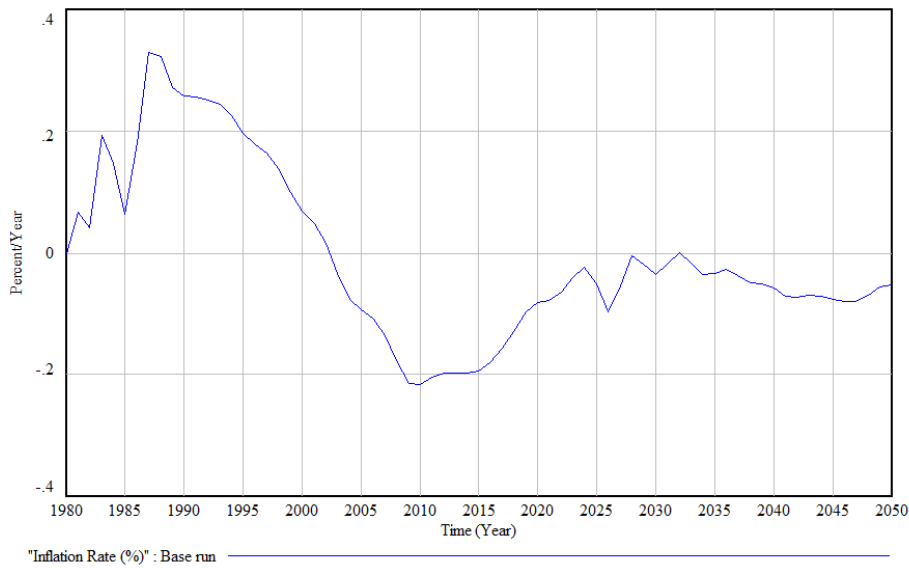


Figure 23: Inflation and Deflation caused by Demand-pull or Supply-push

ulation sub-model are used from corresponding historical data.<sup>23</sup> Then, parameters around the population sub-model shown in the Figure 12 were calibrated to historical behaviors. Figure 25 compares historical data of demographic changes in Japanese population (called Reference mode in the legend) and the base run simulation results which is separately produced by calibrated model parameters and initial reference data values. The comparison of reference mode (historical data) and base run results show that the population dynamics of our model produces behaviors close to what Japanese population data shows. Figure 25 also shows that productive population of Japan reached its peak level in mid 1990's and started to decline afterwards. As mentioned earlier, this declining productive population is affecting the overall trend of diminishing growth rate of potential output.

### GDP Growth and Call Rate

Behavior of call rate under the base run case is shown by a blue line in Figure 35 below. As explained earlier, call rate continues to decrease as central bank is assumed to purchase government bonds continuously. Under such a case, positive correlation between call rate and growth rate of real GDP is observed even though the cause and effect relationship between bank lending rate and desired level of capital is negative in our model as indicated by a red arrow at the bottom left corner of causal loop diagram. Figure 26 shows a phase plot

<sup>23</sup>Data used here is obtained from labor and population statistics compiled by the Statistics Japan of Ministry of Internal Affairs and Communications: <http://www.e-stat.go.jp>

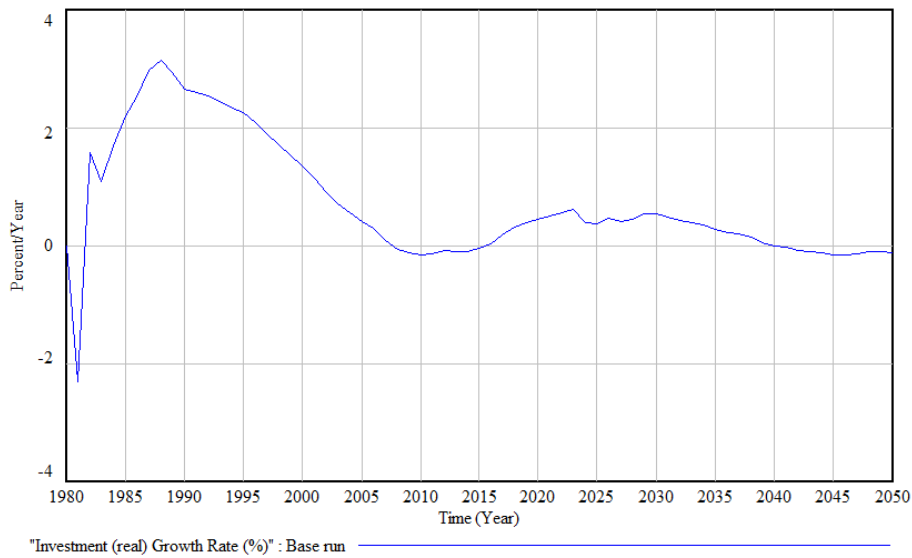


Figure 24: Growth rate of real capital investment

between two variables in general.

### Economic Fluctuations

Another interesting behavior observed in the base run simulation is short-term economic fluctuations. Though they are not obvious enough to be called as business cycles, clearly we can observe economic fluctuations shown by a blue line in Figure 17. How and why are they produced? What is the underlying system structure that causes an economy to fluctuate in the model? As we have seen in the causal loop diagram above, the model embodies both reinforcing and balancing feedback loops with time delays. This structure of balancing feedback loops with time delays in it is being responsible for creating oscillatory movements.

So far, we have here analyzed only several system behaviors observed in the base run simulation.

## 9 Scenario Analysis of Model Behaviors

From now on, let us continue our model analysis by conducting some simulation experiments. The main usage of the model is for an exploratory purpose to analyze interrelationship between five sectors.

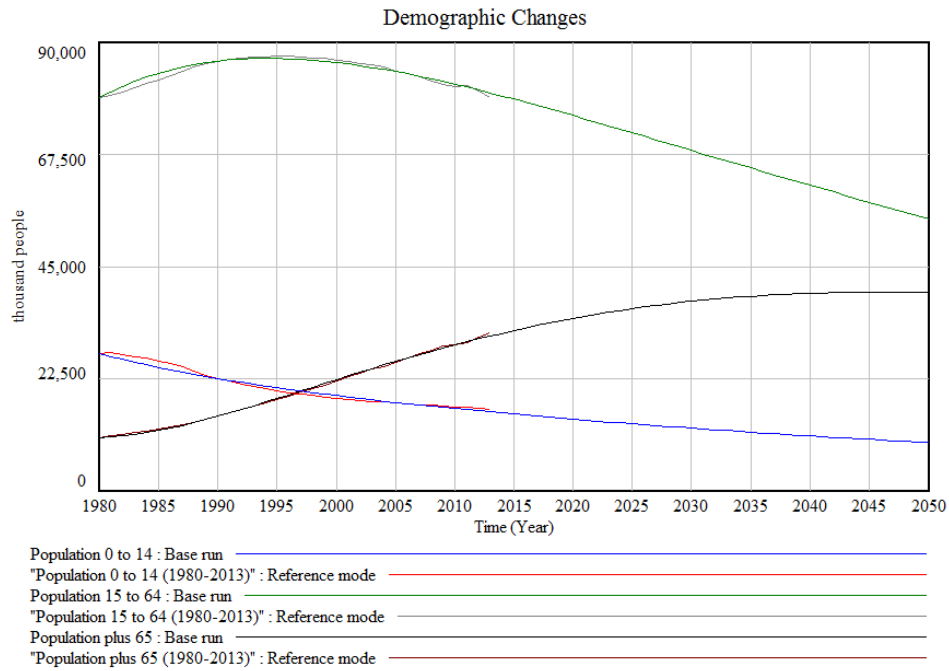


Figure 25: Demographic Changes (Reference Behavior & Base Run)

## 9.1 Business Cycles

### Fluctuations amplified by Inventory Coverage

Let us conduct scenario analyses by changing values of constant variables and exogenous parameters. One of the interesting questions may be to study how business cycles are triggered from milder economic fluctuations seen in the base run case. Similar to the original flow approach model developed by Yamaguchi [15, 2013], the stock approach model turns out to produce business cycles at least by two different ways; that is, by changes in inventory coverage and degree of price fluctuation.

Firstly, it can be caused by increasing a period of normal inventory coverage. Normal inventory coverage in the model reflects an idea of production decision of inventory. That is to say, to what extent an economy as a whole tries to accommodate for inventory adjustment based on the changes in aggregate demand forecasted at every time step, which in turn is formed based on actual aggregate demand with time delays (adaptive expectations). For example, suppose the normal inventory coverage now increases to 0.45 or 5.4 months from the initial value of 0.1 or 1.2 month. The economy, then, begins to be troubled with short term business cycles of 5 or 6 years as illustrated by a red line in Figure 17.

Comparing with the base run case (blue), the economy experiences even

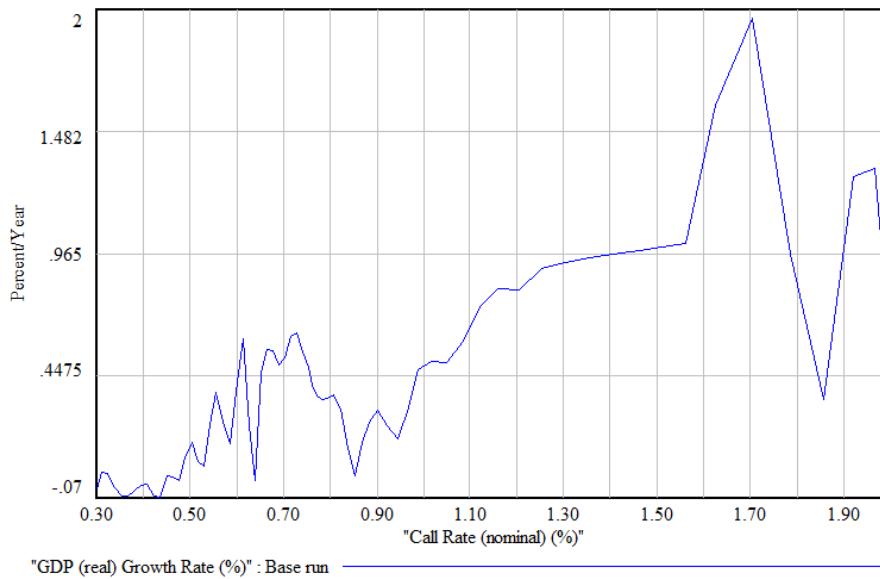


Figure 26: Positive correlation observed between growth rate and call rate

higher demand in early simulation phase, thereby leading to a lower level of GDP gap around that period. However, as the economy begins to slow down starting at around the year 2000, aggregate demand falls, making the GDP gap to widen from the year 2000 until it hits its bottom at the year 2013. Similar to the base run case analyzed above, the economy finally begins to recover from a long term recession as the consumption-driven growth loop (R4) begins to take over a dominance over the behavior of aggregate demand.

Figure 27 compares behaviors of inflation rate with base run. It shows that fluctuations in price level is also amplified especially once the economy begins to gain momentum after more than 20 years of GDP gap.

### Fluctuations amplified by Elastic Price Fluctuation

Secondly, the equilibrium growth path can also be broken by business cycles in a totally different fashion. That is by price fluctuations. Price can be fluctuated by changes in its elasticity and cost-push factor such as changes in wage rate in equation (43). Let us consider the former one by assuming that the response of price level to an excess demand for products becomes more sensitive so that output ratio elasticity now becomes more elastic. This is done by increasing the value of output ratio elasticity by 0.6 from 1 to 1.6 in the base run. Once again, the economic fluctuations are amplified and the economy is thrown into a short-term business cycles as portrayed in Figure 28 and 29. Compared to the pervious case of inventory coverage, the length of a cycle is shorter and the economy cannot attain equilibrium states due to more elastic changes of price.

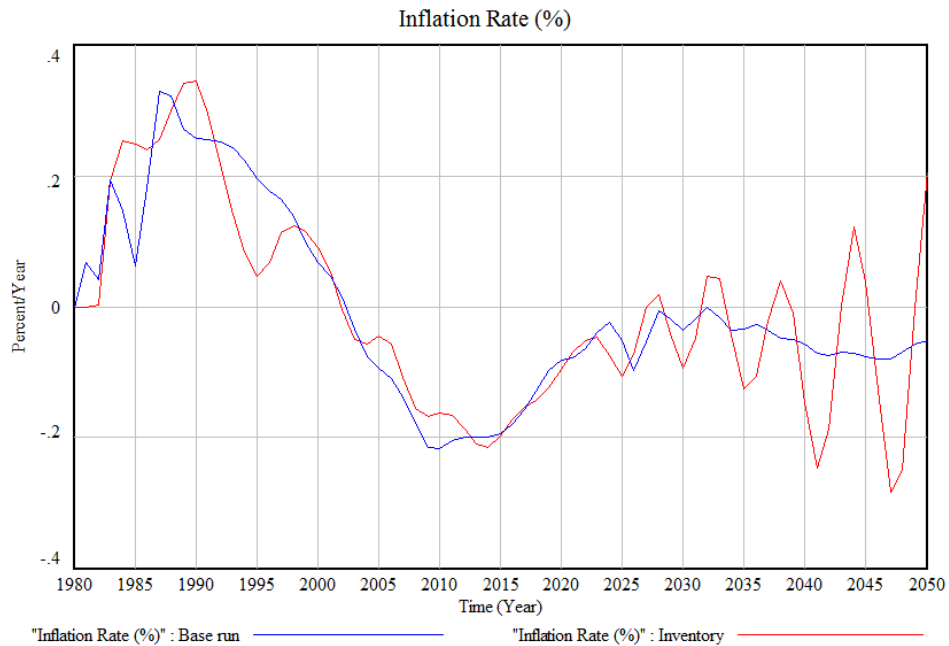


Figure 27: Price Fluctuation amplified by Inventory Coverage

## 9.2 Effects of Monetary Easing

### Temporary Reduction of GDP gap

In the base run case, there is a GDP gap starting to get wider in the second half of 1990's. Observing this trend, let us assume that central bank now decides to stimulate (capital) investment by easing the cost of credit through monetary policy. Specifically, we assume that central bank finally decides to implement market purchase operation starting from 2006 for 2 years by increasing the yearly purchase amount of government bonds by 1.5% of all bonds held by banks. As a result, supply of reserves temporarily increases compared to the base run case (blue line) as illustrated by a red line in Figure 30. This simulation run is named as Monetary Easing 1.

Figure 35 illustrates changes in call rate and prime lending rate realized by monetary easing policy. As explained earlier, all other interest rates are assumed to move in lockstep with call rate. Consequently, a change in call rate caused by the monetary policy is directly reflected to prime lending rate. This monetary easing policy turns out to be effective in alleviating the GDP gap between years 2006-2017 during which the economy has suffered most under the base run case as shown by a red line in Figure 31 and Figure 32.

Furthermore, let us examine a case where the central bank implements another monetary stimulus by introducing another series of market purchase op-

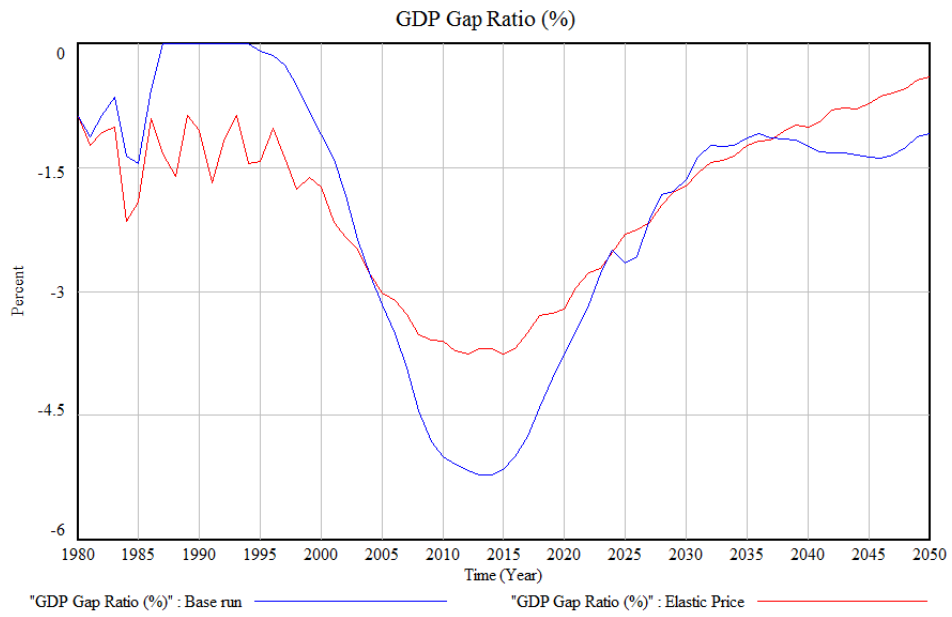


Figure 28: Economic Fluctuations amplified by Elastic Price

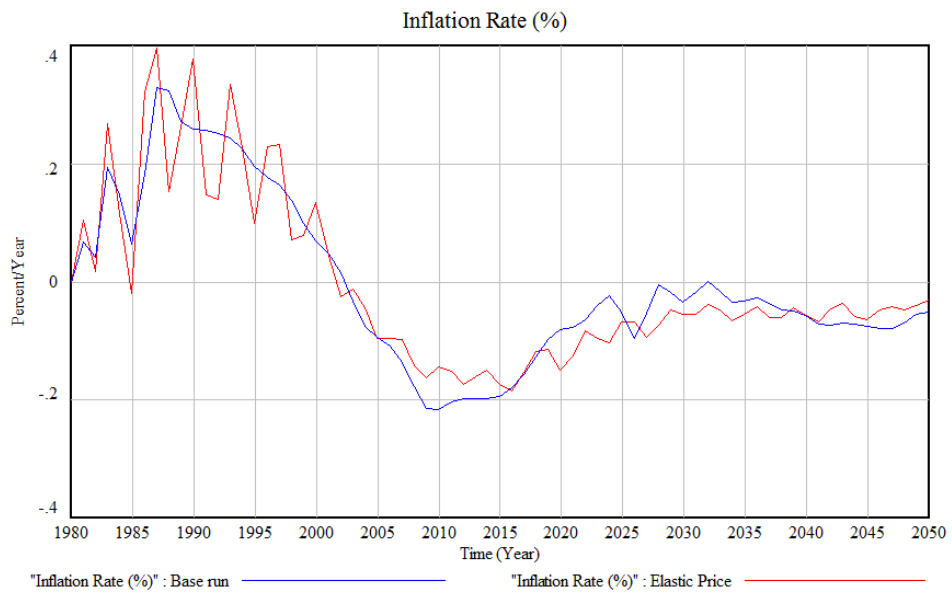


Figure 29: Price Fluctuation amplified by Elastic Price

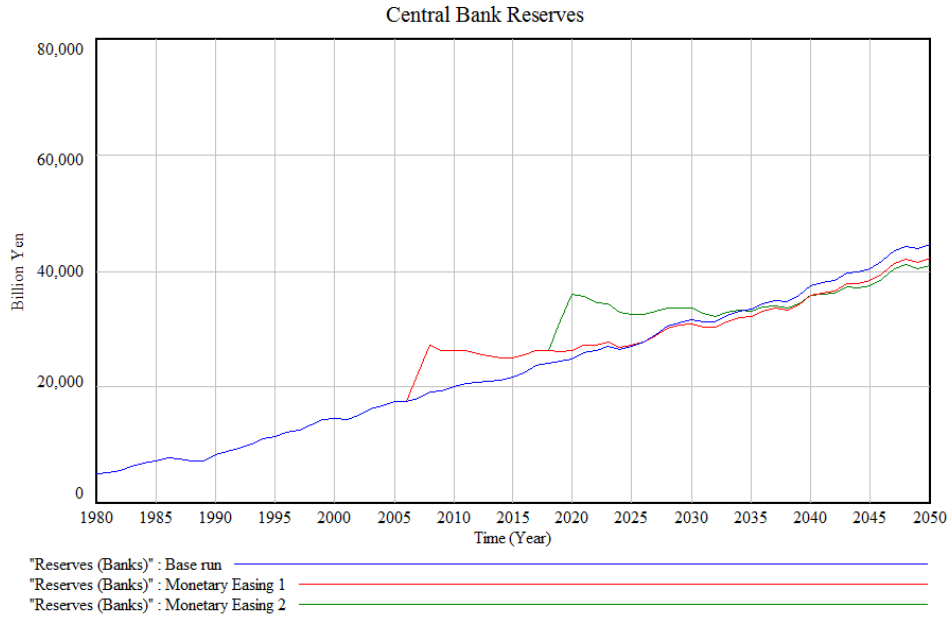


Figure 30: Injection of Reserves at  $t=2006$  and  $t=2018$

eration 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 30, 31 and 32. As a result of the second series of monetary easing (Monetary Easing 2), both call and prime rates are further lowered as shown by a green and light blue line respectively in Figure 35. This decrease in interest rates seems to stimulate capital investment in the economy effectively, resulting in a further reduction of GDP gap from 2018 compared to the monetary easing 1 case (red line) as shown in the Figure 31. 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, being driven largely by consumption-driven growth loop (R4) as similarly analyzed in base run case. Figure 32 compares different growth paths of real GDP under these scenarios

### Growth in Bank Lending and Money Supply

Figure 33 compares growth rates of bank lending and  $M_1$  for different simulations under base run (blue and grey), monetary easing 1 (red and black) and monetary easing 2 (green and brown). At year 2007, we see immediate effects of the first round of monetary policy increasing the growth rate of bank lending shown by a red line. An increase in bank loans surely increases money stock of



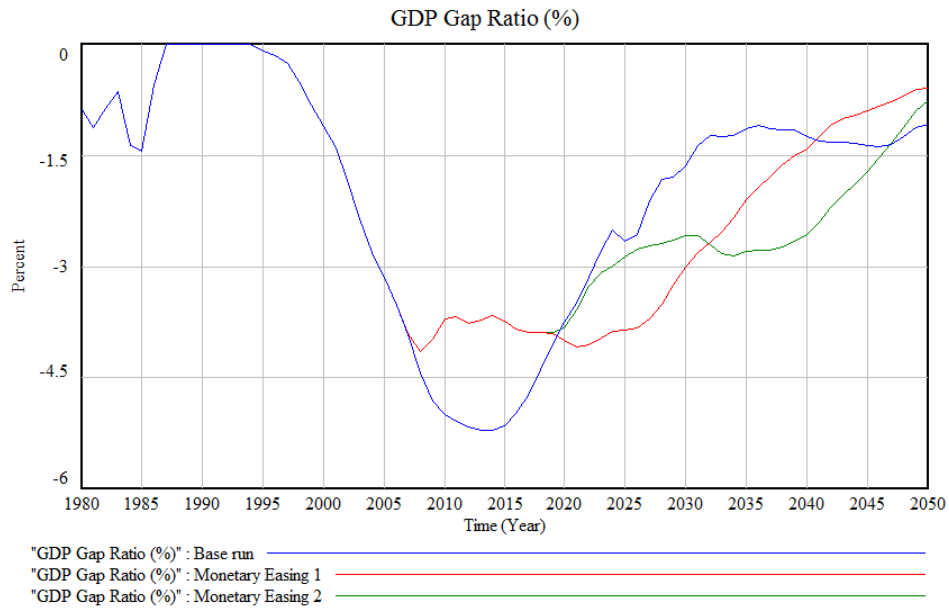


Figure 31: Monetary Easing reduces GDP Gap temporarily

the economy, which is illustrated by a black line. Similarly, a second round of monetary easing starting at year 2018 also turns out to be successful in stimulating investments, increasing bank lending (green line) and money stock (a brown line) respectively from year 2019.

### Temporary Reduction in Deflation Rate

Let us now take a look at this case from a different perspective. Figure 34 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 monetary policy is pulled up after 2 years, the economy is thrown back into deflationary path again. A green line in the same Figure 34 shows temporary improvements in inflation rate kindled by the second series of monetary easing. However, the effects of monetary easing 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 recessions in fundamental level caused by low level of aggregate demand.

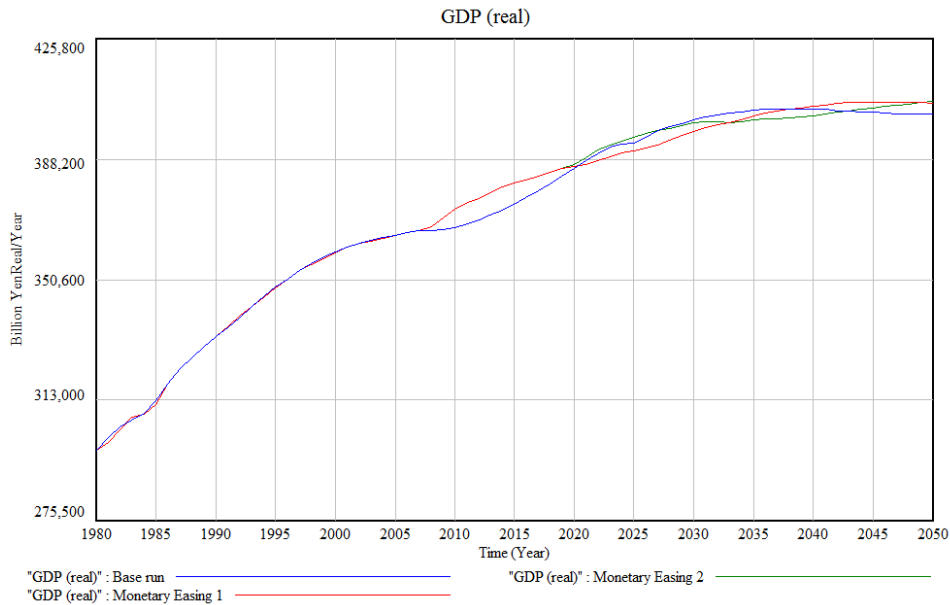


Figure 32: Monetary Easing Policy temporarily alleviates Recession

### A Wishful Thinking in Monetary Policy Transmission Mechanism

Before we move on, a quick remark on an assumption made in our model may be relevant to understand the temporarily observed effectiveness of monetary easing policy. The primary reason why lowering of call rate, and thus lowering of bank lending rate becomes effective is due to our particular assumption in monetary policy transmission mechanism and its channels. That is, the demand for investment is sensitive enough to a change in the prime lending rate. Thus a reduction in prime rate immediately and directly stimulates desired capital investment. This assumption of negative cause and effect relationship between lending rate and desired capital investment is shown by a red arrow at the bottom left corner of causal loop diagram. However, there is no guarantee that this relationship always holds. In fact, this may become a wishful thinking in implementing monetary easing policy as evidenced by the case of Japanese economy since the bubble burst in early 1990's, and other major economies since the global financial crisis.

## 9.3 Effects of Monetary Tightening

### Slowing Down the Economy Successfully

Let us now examine an opposite case of monetary easing. As seen in base run case above, the model economy attains equilibrium during a period between 1987-1994 and the growth rate of real GDP reaches 2.0 % at its peak in the year

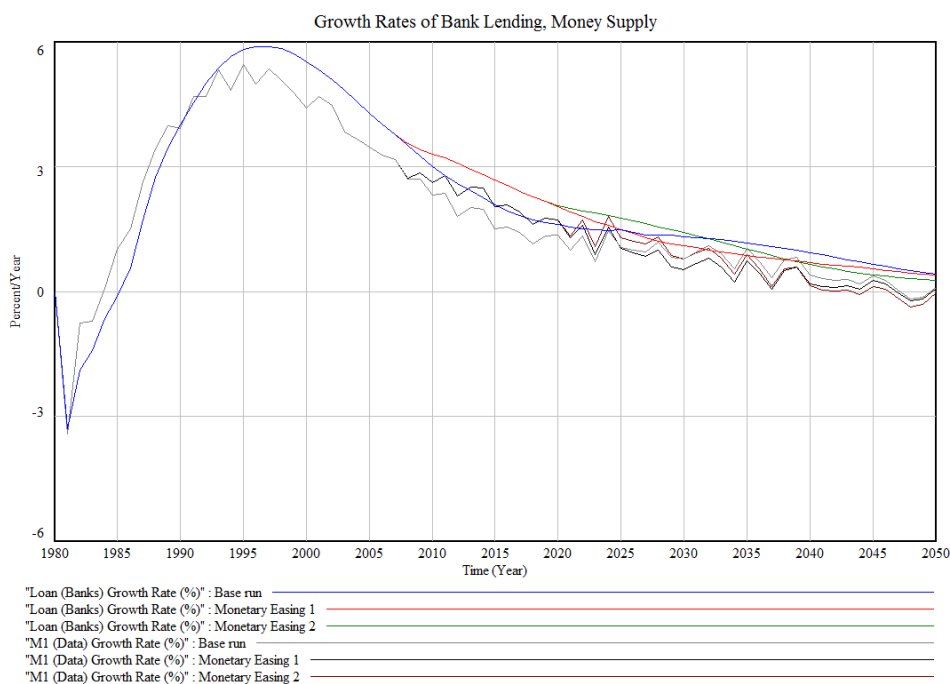


Figure 33: Growth of Bank Lending and Money Supply

1986. The economy is in a boom. What would happen if central bank decides to change its monetary policy rate and tighten a condition of bank credit to slow it down? This scenario of Monetary Tightening 1 is done by increasing the sales amount of government bonds by 5% of its own bond holdings from year 1985 for 2 years. As shown by a red line in Figure 36, supply of reserves is decreased as a result. The reduction in (excess) reserves held by banks affects the supply and demand relationship. This would create an upward pressure on call rate, and lending rate as an opposite case to the monetary easing. With a higher interest rate, demand for investment goes down *ceteris paribus*. Caused by this lack of investment demand, the equilibrium state attained in the base run is now broken and the economy experiences GDP gap as reported by a red line in Figure 38.

### Lagged Effects of Monetary Tightening Policy

A red line in the same figure 38 shows a lagged effects of this monetary tightening policy. The observed time delays between the implementation of monetary tightening at year 1985 and disequilibrium initially observed in year 1987 originates from time delays assumed in the adjustment process of desired level of capital, which is determined partly due to the adaptive formation of long-term aggregate demand forecasts. In other words, it takes time for effects of mon-

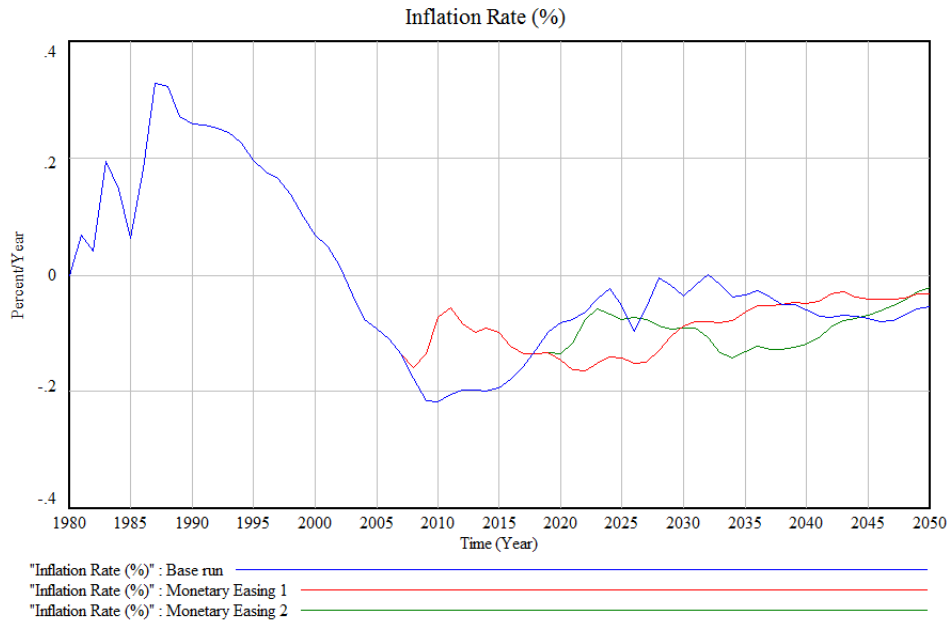


Figure 34: Effect of Monetary Easing on Price Level

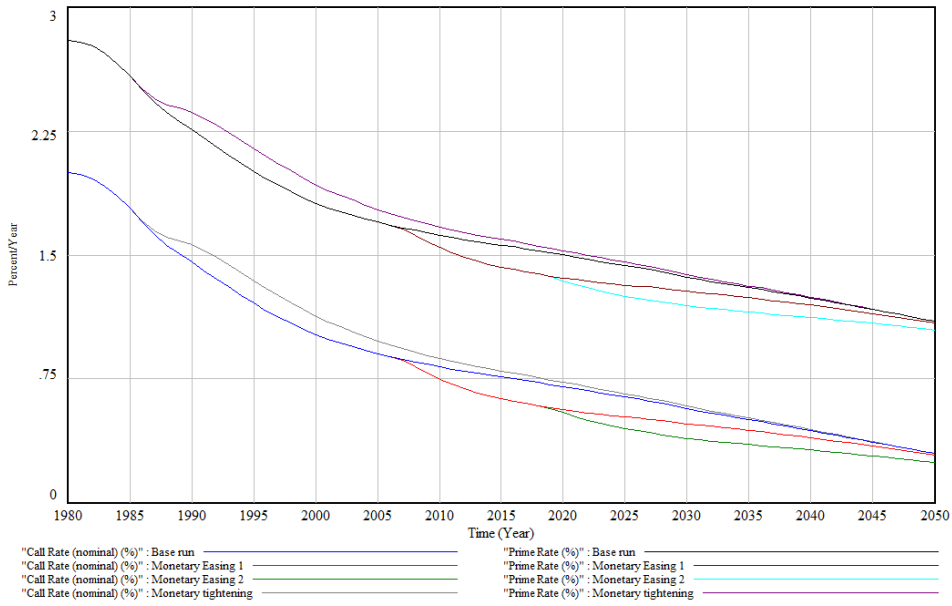


Figure 35: Effect of Monetary Easing and Tightening on Interest Rates

etary tightening policy to actually start to alter economic conditions (such as the aggregate demand forecasts of producers in the model) and cool down the economic boom.

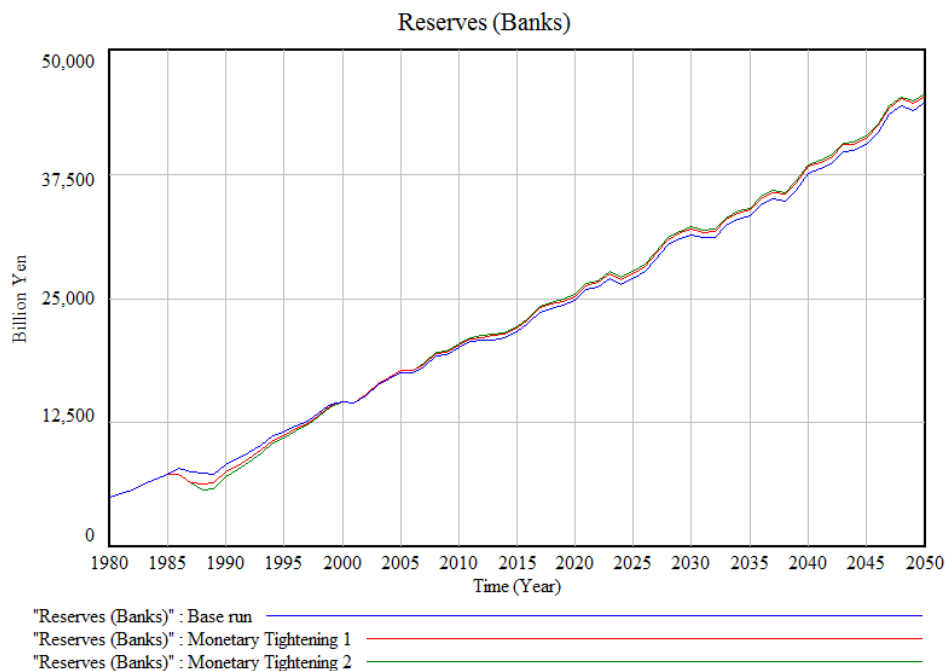


Figure 36: Decrease in Reserves under Monetary Tightening Policy

Let us take a look at this effects of monetary tightening from different perspective. Figure 37 compares changes of price level under base run (blue) and monetary tightening 1 (red). Introduction of monetary tightening policy from year 1985 slows down the demand, decreases investment, and thus reducing the GDP, and worsening the GDP gap. As a result, the economy experiences temporary decrease in inflation rate for 3 years before the it bounces back from year 1990. Soon after the policy is pulled up in 1987, the economy goes back to its original growth path and inflation rate continues to grow until year 1997. This is largely driven by the enduring momentum of the economy sustained from its early phase as similarly observed and analyzed in base run case.

**Pipeline Effects causes Excess Monetary Tightenings**

In our simulation experiment above, it has shown that changes in monetary policy could have significant effects on the economy. With such ability of central banks to influence the economy, what happens if they failed to take proper account of lagged effects of monetary policy observed above? More specifically, what would happen if the monetary policy council fails to fully recognize the

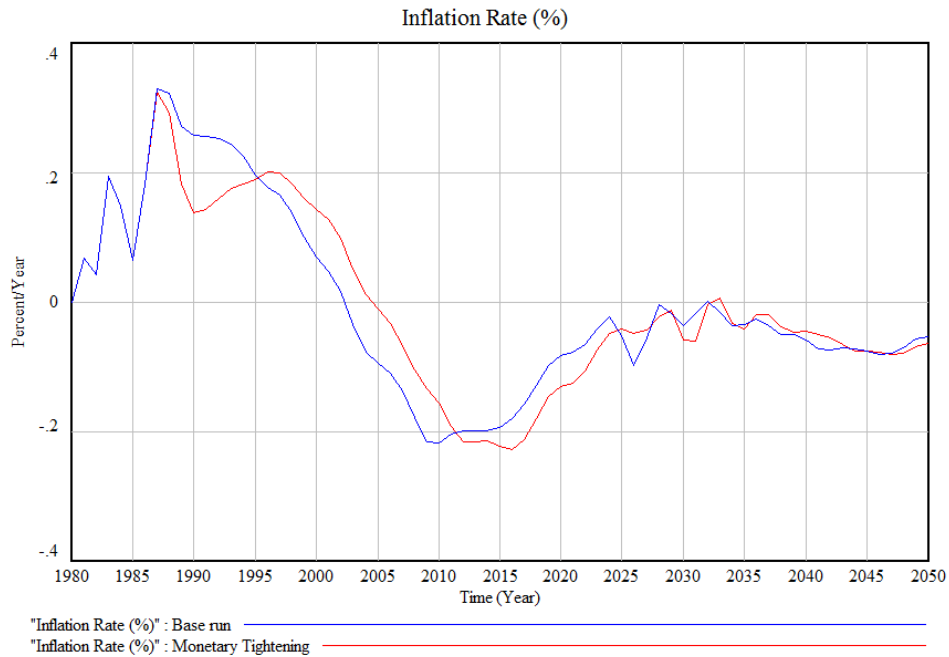


Figure 37: Effect of Monetary Tightening on Price Level

latent effect of the previous policy actions on the economy and keep the same policy for too long?

To examine such a case, let us assume that the central bank at year 1987 (or at the end of year 1986), observing continuous increase in inflation rate and growth of output even after 2 years from the policy implementation in 1985, decides to keep the tightening policy and see what happens for the next 2 years. In other words, central bank keeps the previous policy action as it is for another 2 years until 1988. This scenario is named Monetary Tightening 2. A green line shown in Figure 38 illustrates an unintended policy effects caused by such decision making environment. The continued monetary tightening policy until the end of 1988 (or the beginning of 1989) is shown to cause GDP gap and instabilities to the economy. This lagged effects from the previous monetary policy action is well known by policy makers themselves as *pipeline effects*.<sup>24</sup> A failure in recognizing the pipeline effects can occur not just by the slow changes in the system but when there are delays in the measurement and reporting process of economic data, or by delays between decision making and implementation of the decision.

<sup>24</sup>For example, Alan Blinder, a former vice chairman of the the Federal Reserve System, points out the practical difficulty in estimating pipeline effects in a quantitative manner, and the significance for having such practical measures. [1, 1997].

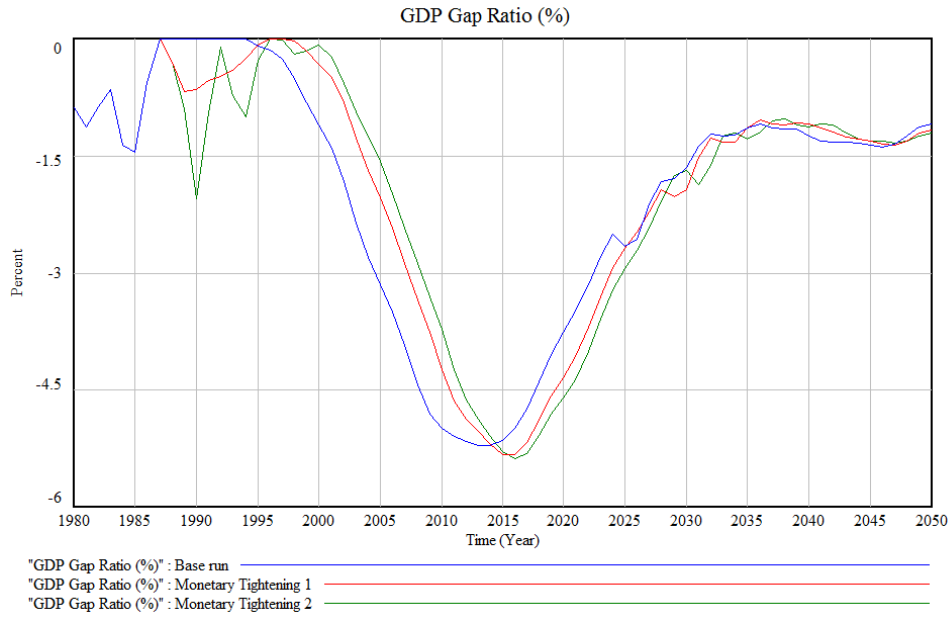


Figure 38: Policy Overstay causes Recession and Instability

## 9.4 Effects of Fiscal Reform

### Tax Increases cause Recessions

From the above scenario analysis, the model turns out to produce different modes of short-term behaviors such as business cycles, an improvement in GDP gap by monetary easing policy, or disequilibrium caused initially by changes in monetary tightening policy by the central bank.

In the base run case (as illustrated in Figure 20), the government debt continues to grow at an exponential rate even under the balanced budget in primary balance. Let us assume that the government now decides to implement fiscal reform by raising tax rates in an attempt to mitigate this problem. Our model provides quite a few tools to study such a case, such as corporate tax rate, excise tax rate, lump-sum tax rate. In the current analysis, income tax rate and excise tax rates are chosen.

Because the economy is facing a relatively higher growth rate during the early phase, let us assume that the government seeks to implement a tax rate while the economy is growing in the hope that this would reduce public debt accumulation without causing repercussions on the economy. More specifically, the government increases the income tax rate by 3%. That is, the income tax rate is increased from 12% to 15% from year 1988 for 10 years. Furthermore, the excise tax rate is additionally increased by 3%, changing the previous rate from 5% to 8% permanently starting from year 1995. In order for the government to reduce its

debt, spending must be cut relative to tax revenues. To do this, the government now lowers its expenditure by 5% of the tax revenues, that is the primary balance ratio is now set to  $\mu = 95\%$  from year 1988, incurring fiscal surplus for 10 consecutive years. This scenario is named Fiscal Reform 1. A red line in Figure 39 shows temporary but successful reduction in the growth of government debt accumulation for 10 years under Fiscal Reform 1 case. It is shown that this leads to a lower level of government debt throughout the simulation time in comparison with base run scenario.

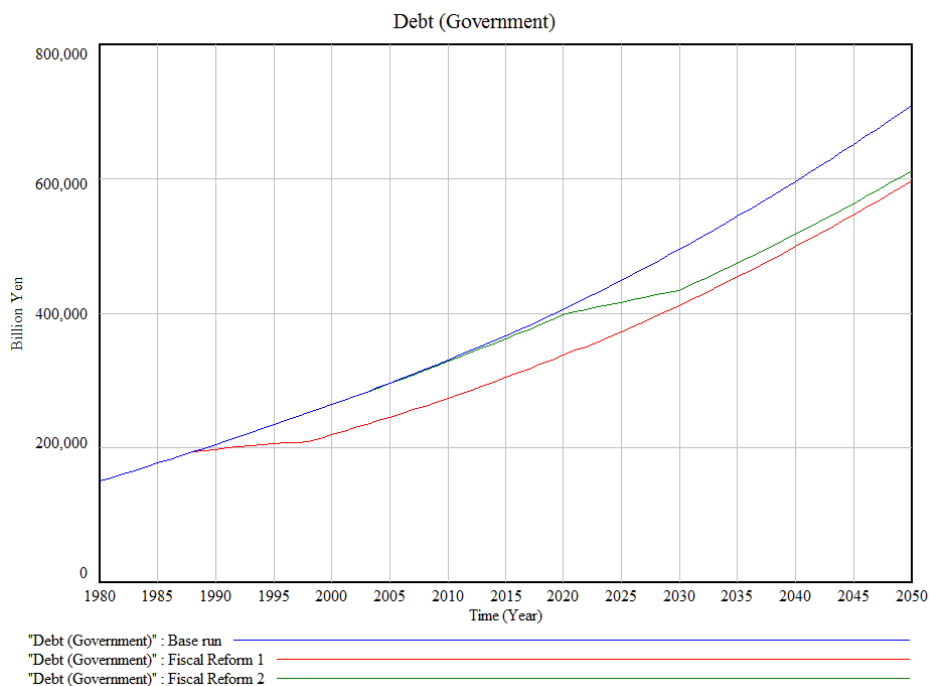


Figure 39: Reduction in Government Debt Accumulation by Tax Increase

What happens to the real economy then? A red line in Figure 40 illustrates how GDP gap is affected by the introduction of fiscal reform program compared to the base run case (blue). As shown, increase in income tax rate at year 1988 and simultaneous decrease in the government spending affect the real economy and break the equilibrium path between 1987. Furthermore, a permanent increase in excise tax rate starting from year 1995 causes economic growth to slow down significantly from 1995 onwards and creates instabilities.

### Different Effects of the Same Tax Increase

Let us now examine a same fiscal reform case but implemented under different state of the economy. What would happen if the government, fearing that tax



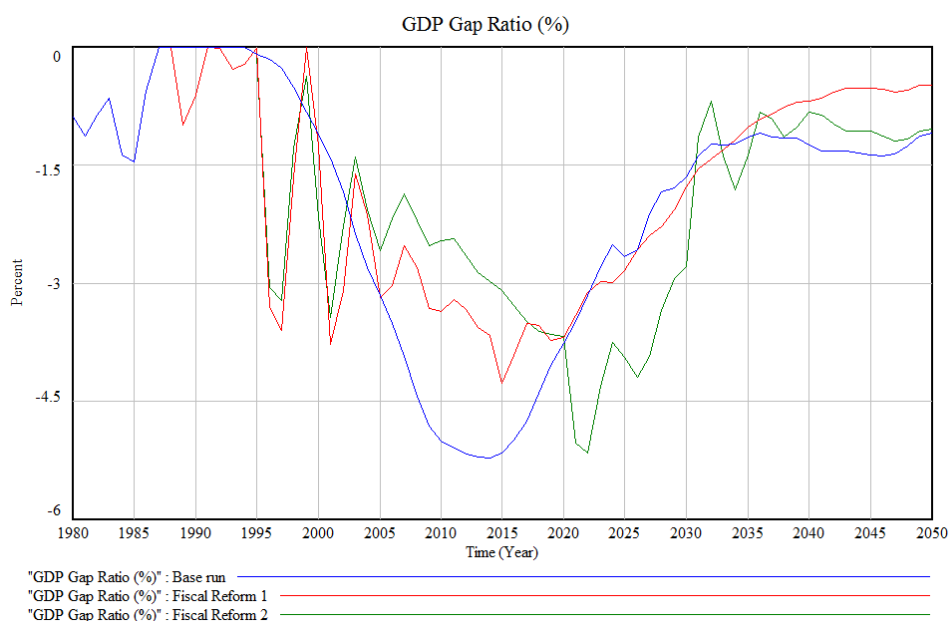


Figure 40: Different Effects of the Same Tax Increase on Output

rate hike would slow down the economy, decides to post pone income tax rate increase in the previous case? Can it attain a similar reduction of government debt without worsening GDP gap? Under the base run case, the economy enters long-term recession and deflation around year 1995. Seeing this, the government decides to wait fiscal reform until they perceive that the economy is finally catching up. This is done by postponing starting time of income tax rate hike until 2020. Specifically, the government implements increase in excise tax rate from year 1995 as in the previous case. Then, the government increase the income tax rate from year 2020 by the same value as in the previous case. This scenario is named Fiscal Reform 2.

As shown by a green line in the Figure 39, increase in income tax rate and decrease in government spending contributes to a reduction in the growth of government debt accumulation. A green line in the Figure 40 reports the effect of fiscal reform 2 on GDP gap. It is shown that the economy's equilibrium state in the early 1990's is not broken, yet the same change in excise tax rate in 1995 causes GDP gap as in the previous case of fiscal reform 1. Furthermore, a hike in income tax rates and reduction in the government expenditure from year 2020 worsens the gap compared with base run case and fiscal reform 1.

## Difficulty of Fiscal Stabilization

Two fiscal reform scenarios were considered where the government tried to reduce the growth of public debt by raising tax rates and reducing the spending under different economic conditions. In the first case, the government implemented tax policy when the economy exhibits relatively stronger growth. In the second fiscal reform case, tax raising policy was implemented when the economy is about to recover from long-term recession and different consequence on the real economy were observed. More importantly, two simulation experiments implies the difficulty of keeping debt accumulation from growing without causing adverse effects on the economy both under growth and recessionary phase.

## 9.5 Differing Effects of Fiscal Stimulus

### Fiscal stimulus disturbs equilibrium state

We have just examined cases of fiscal reform. Let us now examine effects of fiscal stimulus policy implemented under three different economic conditions observed in the base run case: growth, recession and the recovery phase. Specifically, the government increases its expenditure by increasing the primary balance ratio  $\mu$  by 5% (0.05) starting from year 1986 for 5 years for the first case. This scenario is called Fiscal Stimulus 1. In the second case, the government implements the same fiscal policy from year 2006 in an attempt to mitigate the recessionary path, which is getting worse since 2000 in the base run case. This case is called Fiscal Stimulus 2. Lastly, the same policy is implemented from year 2020 in the third case where the government, having observed the long-term recession, hopes to accelerate the economic recovery starting to be felt from year 2015 in the base run. This last scenario is called Fiscal Stimulus 3.

Figure 41 compares base run with three different fiscal stimulus cases. Comparing base run case shown by a blue line, it is shown that the stimulus policy implemented under high economic growth phase (red line) disturbs equilibrium paths from 1989, creating fluctuations in the system. On the other hand, the same fiscal policy implemented when the economy is experiencing recessionary pressure (green line) temporarily alleviates the GDP gap for a period of 5 years as shown by a green line in the same figure. However, soon after the policy is dropped in year 2011, the economy is thrown into recession and GDP gap hits 7%, exceeding that of the base run case. A grey line in the same Figure 41 shows the different effects on the economy under Fiscal Stimulus 3 case. Policy implementation from year 2020 (grey line) contributes to the ongoing recovery from the long-term recession and turns out to improve the economic condition by raising aggregate demand through government expenditures. Interestingly, these simulation results showed that the same fiscal stimulus policy of raising the government expenditures led to different effects when they were implemented under different state of the economy.

Figure 42 compares velocity of money under four scenarios tested above. This type of agile fiscal stimulus surely accelerate the velocity of money. A comparison of these two cases suggests that government spending aimed at

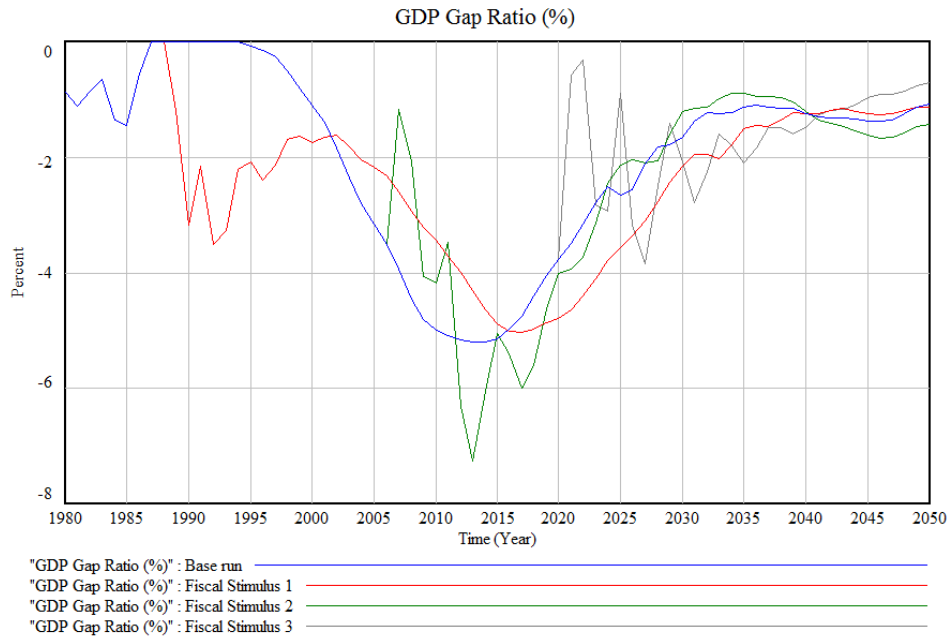


Figure 41: Differing Effects of Fiscal Stimulus

creating demands in the economy could have positive effects during a period of economic stagnation, while the same fiscal policy implemented during a period of high growths could result in destabilizing a self-regulating feedback mechanisms within the macroeconomy.

## 9.6 Credit Crunch

### Recessions caused by Credit Crunch

Let us now examine a situation where banks all of sudden become wary of lending to producers sector, thus lowering the amount of bank lending. This is known as *credit crunch*. In a real world, this kind of sudden changes in bank lending conditions could originate from number of factors, such as downgrading of credit ratings often as an extension of financial crisis. In our simulation analysis, we do not specify how it is triggered but simply assume that there was a sudden shock in bank lending condition. Specifically, we assume that banks now decrease the amount of lending when the economy is in equilibrium states to study an implication of credit crunch on the growth path of an economy. In the model this can be expressed by a sudden increase in lending disapproval ratio by 15% from year 1987 for 2 consecutive years. This scenario is named as Loan disapproval and is shown by a red line in the Figure 43. Compared with base run (a blue line), credit crunch caused by an increase in loan disapproval

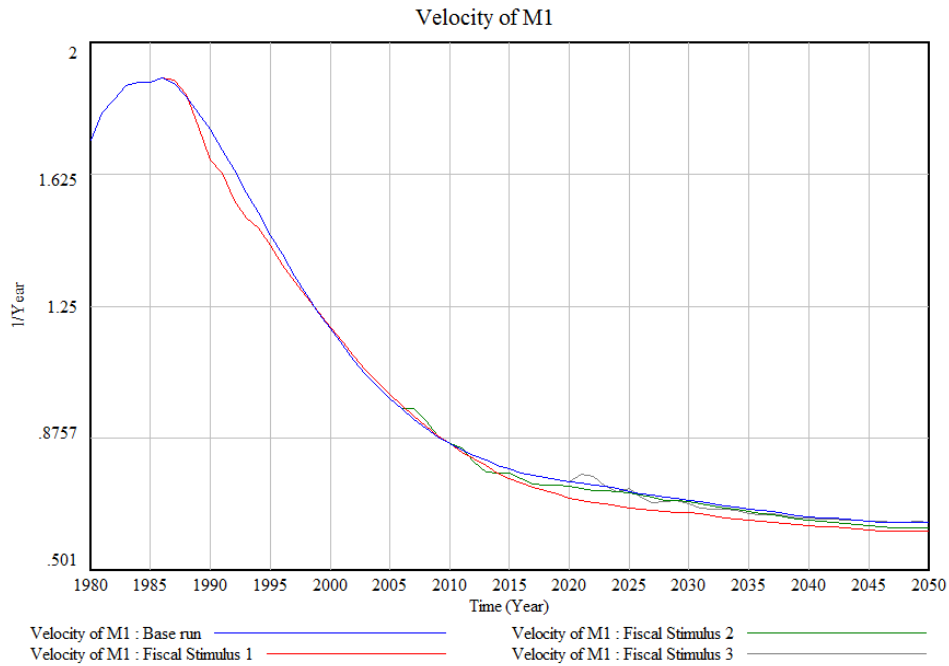


Figure 42: Different Velocity of Money affected by Fiscal Stimulus

ratio immediately causes recession and GDP gap drops as close as 3% at year 1989 and 1994.

How is this happening? Figure 48 shows the amount of bank lending to producers sector. As illustrated by a red line, banks kept the amount of lending at about the same level from year 1987, which leads to the disequilibrium. Furthermore, unstable behaviors of bank lending is observed, which are reflected by the economic fluctuations captured by the GDP gap shown by a red line in the Figure 43. What happens to money stock during this period? Figure 44 compares growth rate of money stock in base run (blue) and loan disapproval scenario (red). Decrease in bank lending surely results in decrease in the growth rate of  $M_1$  from year 1987.

### Recession caused by Currency Ratio Shock

Finally, as our last case, let us examine how credit crunch can also be caused by a sudden shock in currency holding ratio of households. Currency ratio shock that we are examining here involve a sudden and substantial increase in demand for cash withdrawal by depositors in the real world. In the model it is assumed that households decide to increase their cash holdings, which is determined as a certain fraction of their demand deposits in the model. This scenario can be tested by exogenously increasing the currency (holding) ratio of households by

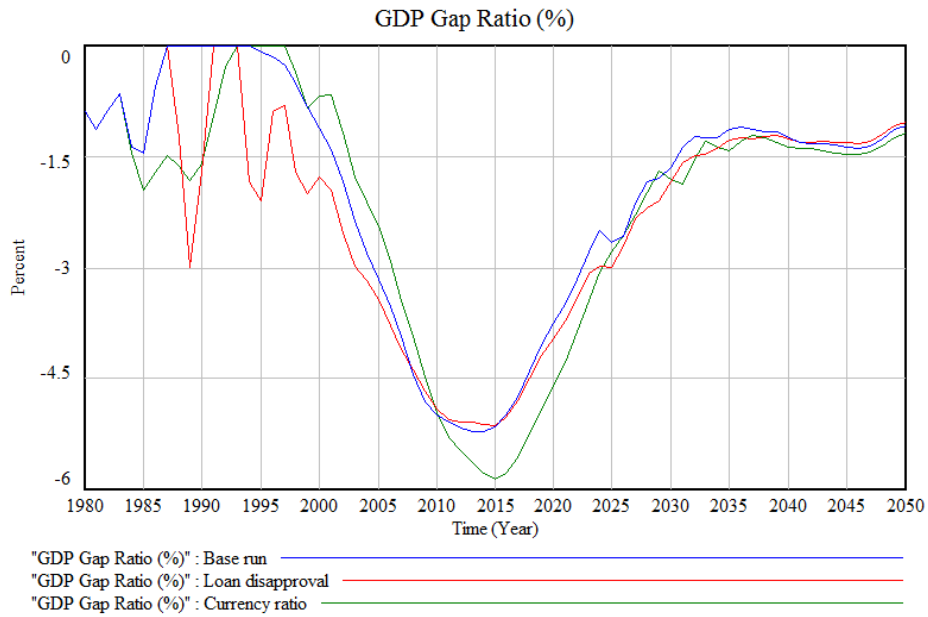


Figure 43: Credit Crunch amplifies Instability and worsens Recession

3% from 1% to 4% starting at year 1982 for 5 consecutive years. Figure 45 shows behaviors of cash held by households sector and reserves by banks under this case compared with base run. As shown by red and grey line, jump in household's cash (red) decreases the reserves (green). Since banks are assumed to always keep certain amount of vault cash in order to meet the cash demand in our model, an increase in cash withdrawal directly affects bank's demand for vault cash from central bank (as explained in Table 3 in section 2.5).

As in other cases, changes in the supply of reserves affect call rate. In this case, decrease in reserves supply puts upward pressure on call rate. Figure 46 shows this behavior of interest rates hike caused by cash demand shock and the lockup movement of prime lending rate with call rate. A blue line in the Figure 46 illustrates behavior of call rate under the base run while a red line shows the behavior of call rate under currency ratio case. Green and grey line illustrates behaviors of prime lending rate under base run and currency ratio cases respectively.

As in other scenarios, an increase in prime lending rate affects demand for capital investment. A green line in the Figure 43 shows that equilibrium states at a period between 1987 and 1994 attained in the base run is broken caused by credit crunch and GDP gap deepens as a result.

The recession caused by currency ratio shock in our model originates from two primary channels. First one is by way of increase in prime lending rate as we have just seen. The other, which is more significant factor than the former,

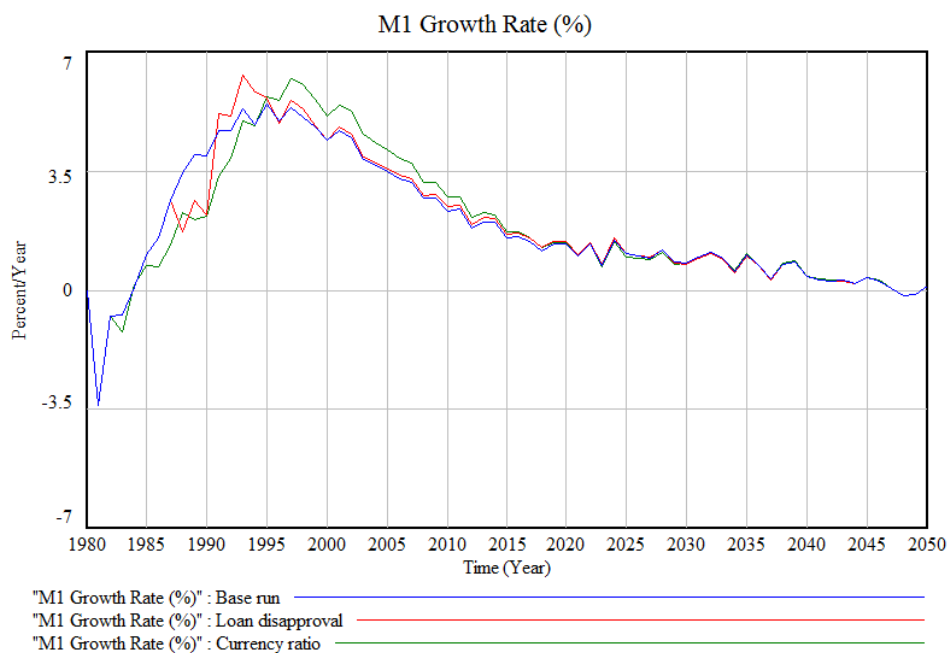


Figure 44: Damped Growth Rate of  $M_1$  caused by Credit Crunch

is due to constraints on loanable funds caused by decrease in reserves supply. As explained earlier, banks lend by creating deposits under the fractional reserve banking system. However, they cannot create infinite amount of deposits. Under the system, the maximum amount of deposits that banks as a whole can create is ultimately constrained by total reserves supply. Large amount of cash withdrawal reduces reserves of banks. Unless the central bank injects additional reserves, this puts further constraints on the maximum loanable funds of banks. Through this chain of events, large volume of cash withdrawal ultimately results in cutting out some of capital investments during the economic growth phase. A green line shown in the Figure 48 illustrates this type of credit crunch. It is shown that from year around 1990, the amount of bank lending begins to grow fast as the currency ratio shock ends and banks finally can start to lend as much as the real economy demands.

Through these two channels, our model of the stock approach successfully describe the effects of sudden increase in currency holding ratio on credit availability, reduction in bank lending, and thus on economic output. The case of credit crunch caused by a currency ratio shock shows that if no additional reserves are supplied during such shock in cash demand, it could have an adverse effect on the output of the economy. This macroeconomic phenomenon partially reminds us of what happened in the United States during the Great Depression in early 1930's when a nation-wide bank runs, combined with massive reduc-

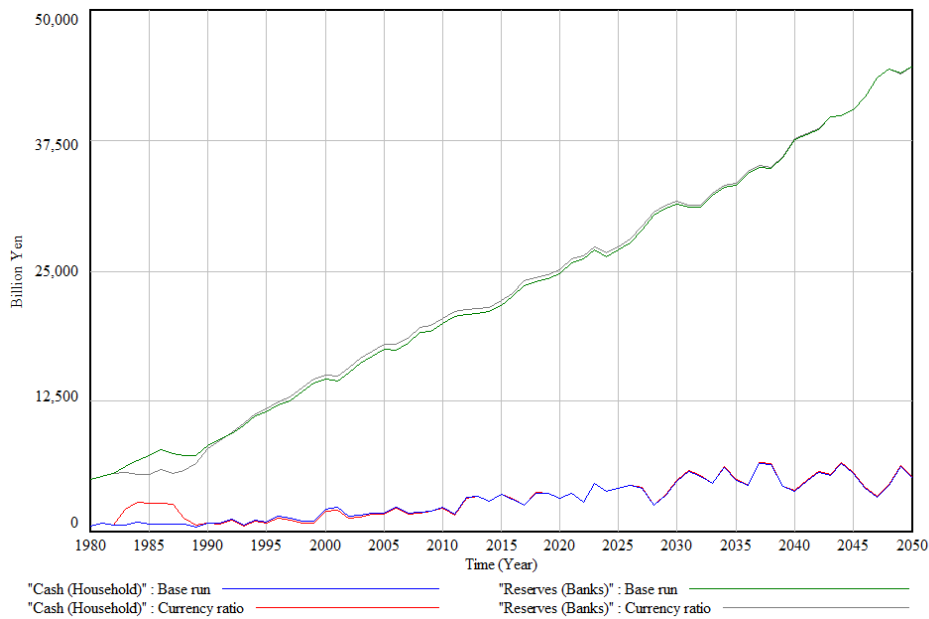


Figure 45: Households increases Cash Demand

tion in bank loans (credit), aggravated the nation's financial system. Fisher [3, 1935] wrote that in 1929, total circulating medium was reported to be 27 billion dollars. Out of the 27 billion, 23 were "check-book money" and 4 were "pocket-book money".<sup>25</sup> This meant that, in the year 1929, currency ratio = (pocket-book money)/(check-book money) =  $4/23 = 17.4\%$ . By 1933, however, the numbers dramatically changed. In 1933, total circulating medium decreased to 20 billion dollars. Out of the 20 billion, 15 were "check-book money" and 5 were held by "pocket-book money". In other words, bank deposits decreased by 8 billion dollars in 4 years while amount of cash increased by 1 billion, leading to an increase in currency ratio up to  $5/15 = 33.3\%$ .

An essential part of this depression has been the shrinkage from the 23 to the 15 billions in check-book money, that is, the wiping out of 8 billions of dollars of the nation's chief circulating medium which we all need as a common highway for business.(p.15)

Furthermore, the simulation result under currency ratio shock case turned out to be consistent with the analysis done by Yamaguchi et.al [16, 2016] where combined shocks of bank lending ratio and currency ratio are shown to create variability of money stock under the stable base money. This variability of money stock under stable base money is reported in the Figure 47.

<sup>25</sup>Check-book money and pocket book money are original terms Fisher used in [3, 1935]. Check-book money is equivalent to bank deposits, pocket-book money is equivalent to bank cash.

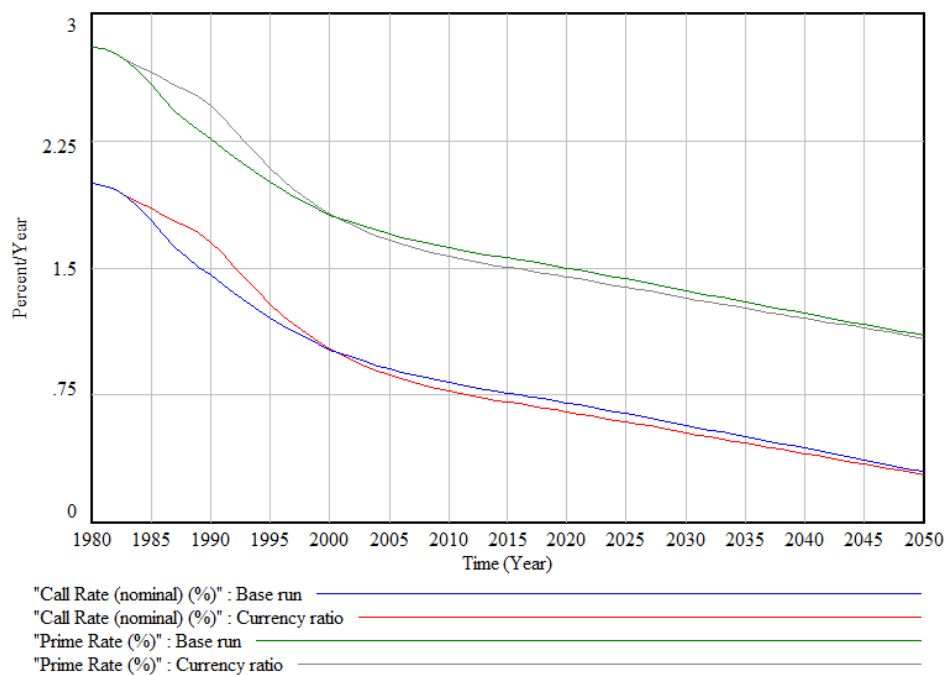


Figure 46: Interest Rates Hike caused by Cash Demand Shock

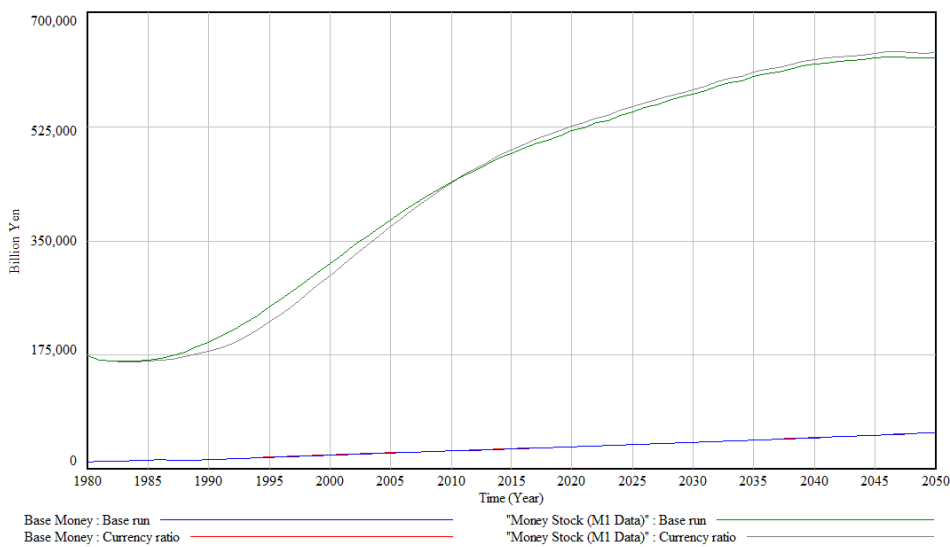


Figure 47: Credit Crunch caused by Shock in Currency Holding Ratio



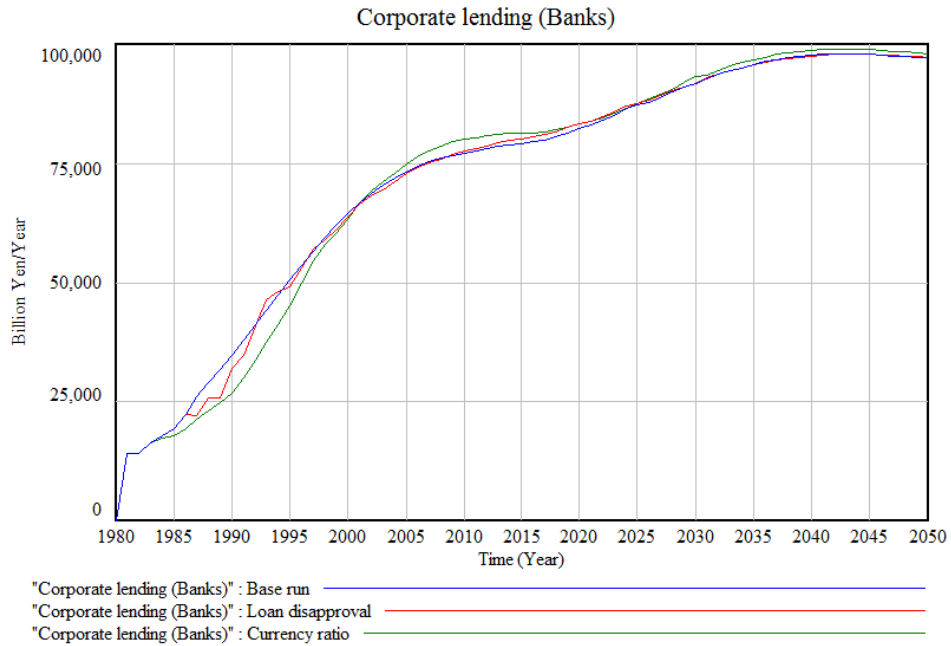


Figure 48: Credit Crunch caused by Two Different Monetary Shocks

## 9.7 Growth Paths of Real GDP

In Figure 49 below, different growth paths of real GDP under different scenarios are compared among 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 different changes in macroeconomic conditions.

## 10 Conclusion

An ASD macroeconomic model of the stock approach consisting of five sectors is developed to better understand how banking and production economy interact. The model turns out to produce diverse macroeconomic behaviors caused by different sources of perturbation amplified by feedback loops in the economy. Firstly, equilibrium and disequilibrium are shown to exist in the base run simulation. The government debt is shown to increase at an exponential rate even under the assumption of a balanced budget in primary balance. Secondly, economic fluctuations observed in base run are shown to be amplified and business cycles are triggered by two different manners; change in inventory coverage period, and elastic price fluctuation. Then, it is analyzed that monetary easing policy becomes effective for alleviating the GDP gap under the specific assumption of

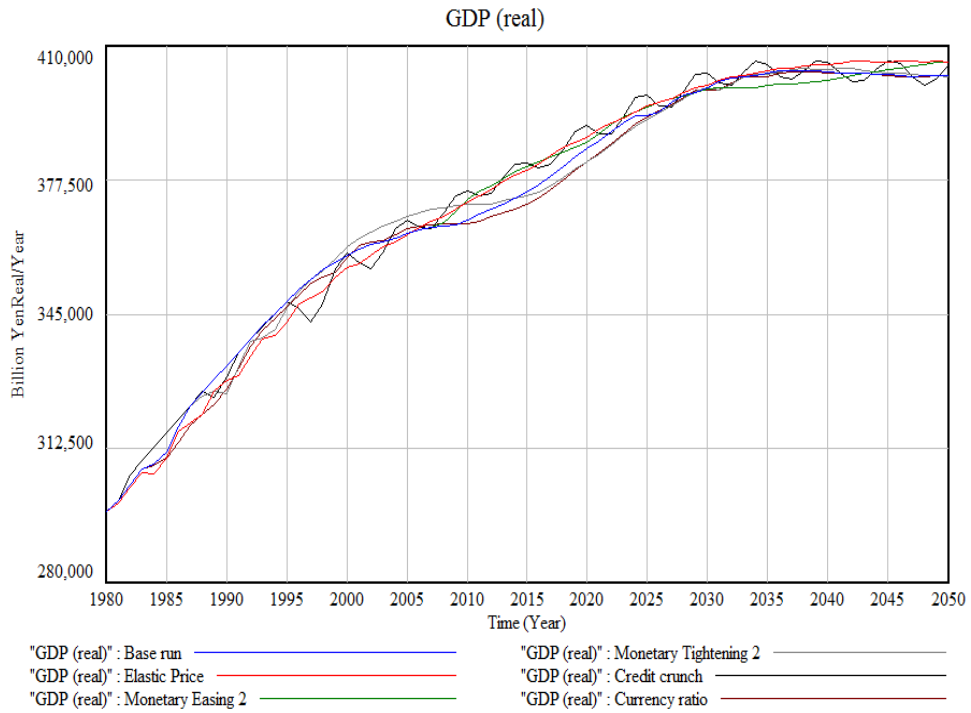


Figure 49: Growth Paths of GDP

monetary policy transmission mechanism. Additionally, monetary tightening scenario is tested and shown to cause disequilibrium. Furthermore two cases where the same fiscal policy implemented under different economic conditions are explored and shown to have differing effects on the economic output. Finally, two cases of credit crunch triggered by two different types of monetary shock are examined to study how they affect the growth path of an economy.

We believe that the generic macroeconomic model of the stock approach presented here could provide a foundation for advanced analysis of a specific case study with actual historical data.

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## **Appendix: An ASD Macroeconomic Model**

All equations, parameters of an Accounting System Dynamics (ASD) macroeconomic model are documented in a supplementary attached below.

## **Model Documentation**

Model Name: MacroSystem (stock approach)  
Date of Production: June 21<sup>st</sup>, 2017.  
Produced by: Yokei Yamaguchi  
Contact: Yokei.Yamaguchi@gmail.com

This document was prepared as a supplement to the master thesis submitted by Yokei Yamaguchi on June 30<sup>th</sup>, 2017, titled: Developing an ASD Macroeconomic Model of Stock Approach – With Emphasis on Bank Lending and Interest Rates.

All equations in the ASD macroeconomic model of stock approach “MacroSystem (stock approach)” are documented in alphabetic order in this supplementary. Total number of equations is reported to be 607 by the software program.

Contents of each equation is organized in the following format:

1. Name of variable or parameter
2. Unit
3. Comment from a modeler (if any)

When equation has no unit, it is a dimensionless shortened as “Dmnl”.

## Model Equations:

FINAL TIME = 2050

Units: Year

The final time for the simulation.

INITIAL TIME = 1980

Units: Year

The initial time for the simulation.

SAVEPER = 1

Units: Year [0,?]

The frequency with which output is stored.

TIME STEP = 0.25

Units: Year [0,?]

The time step for the simulation.

"Actual Currency Ratio (M1)"=

ZIDZ(Currency in Circulation, "Demand Deposits (Banks)")

Units: Dmnl

"Adaptive Prime Rate (real)"= INTEG (

Change in Adaptive PR,

"Prime Rate (real)")

Units: 1/Year

Adaptive Expectations based on the average adjustment time  
horizon of prime rate.

Adjusting Vault Cash=



$$\frac{("Desired\ Vault\ Cash\ (Banks)" - "Vault\ Cash\ (Banks)")}{Reserves\ Adjustment\ Time}$$

Units: Billion Yen/Year

Banks always stay ready for Cash Demand by Households.

"Aggregate Demand (real)"=

$$"Consumption\ (real)" + "Investment\ (real)" + "Government\ Expenditures\ (real)"$$

Units: Billion YenReal/Year

Aggregate Demand Forecasting= INTEG (

Change in AD Forecasting,

INITIAL Aggregate Demand Forecasting)

Units: Billion YenReal/Year

Adaptive Expectations: it takes time to measure, report and change new information of state and adapt the mind (assume first-order exponential smoothing)

"Aggregate Demand Forecasting (Long-run)"= INTEG (

"Change in AD Forecasting (Long-run)",

"INITIAL Aggregate Demand Forecasting (Long-run)")

Units: Billion YenReal/Year

Average college schooling time=

4

Units: Year

"B/S: Banks"=

"Vault Cash (Banks)"

+ "Reserves (Banks)"

+ "Government Bonds (Banks)"

+ "Loans Receivable (Banks)"

- "Debt (Banks)"
- "Demand Deposits (Banks)"
- "Time Deposits (Banks)"
- "Retained Earnings (Bank)"

Units: Billion Yen

"B/S: Central Bank"=

- "Loan (Central Bank)"
- + "Government Bonds (Central Bank)"
- "Currency Outstanding (Central Bank)"
- "Reserves (Central Bank)"
- "Government Deposits (Central Bank)"
- "Retained Earnings (Central Bank)"

Units: Billion Yen

"B/S: Government"=

- "Deposits (Government)"
- "Debt (Government)"
- "Retained Earnings (Government)"

Units: Billion Yen

Base Expenditure=

90000

Units: Billion Yen/Year [0,300000,10000]

Base Money=

- "Currency Outstanding (Central Bank)"
- + "Reserves (Central Bank)"
- + "Government Deposits (Central Bank)"

Units: Billion Yen

"Base Money (strict definition)"=  
"Currency Outstanding (Central Bank)"  
+ "Government Deposits (Central Bank)"  
+ "Reserves (Central Bank)"  
+ "Retained Earnings (Central Bank)"

Units: Billion Yen

Basic consumption=  
60000

Units: Billion Yen/Year [?,?,1000]

Optimized value under "ConsumOpt" settings = 54174.2

births=  
(1-SWITCH fertility)\*constant total fertility  
\* Population 15 to 44  
\* 0.5  
/ reproductive lifetime  
+  
SWITCH fertility\*total fertility  
\* Population 15 to 44  
\* 0.5  
/ reproductive lifetime

Units: thousand people/Year

"births (1980-2013)"

Units: thousand people/Year

"BoJ Note Outstanding (1980-2017)"

Units: Billion Yen

Data Source: Bank of Japan

"Borrowing (Banks)"=

"Discount Window Lending (Central Bank)"

Units: Billion Yen/Year

"Borrowings (Government )"=

Government Securities Newly Issued

Units: Billion Yen/Year

"Borrowings (Household)"=

"Household Lending (Banks)"

Units: Billion Yen/Year

"Borrowings (Producer)"=

"Corporate lending (Banks)"

Units: Billion Yen/Year

C Ratio Change=

0

Units: Dmnl [-0.005,0.08,0.005]

"Demand Deposits (Producer)"= INTEG (

"Borrowings (Producer)" + Newly Issued Capital Shares +  
Sales - "Capital Investment (Producer)"

- "Debt Finance Expenditures (Producer)" - "Equity Finance  
Expenditures (Producer)" - "Payments (Producer)",

"INITIAL Demand Deposit (Producer)"

)

Units: Billion Yen

Adjustment Time of IR=

5

Units: Year [1,6,1]

Adjustment Time of Prime Rate=

7

Units: Year [3,10,1]

Adaptive Expectations based on the adjustment time horizon of  
prime rate.

"B/S: Household"=

"Cash (Household)"  
+ "Demand Deposits (Household)"  
+ "Savings Deposits (Household)"  
+ "Government Bonds (Household)"  
+ "Capital Shares (Household)"  
- "Loans from Banks (Household)"  
- "Retained Earnings (Household)"

Units: Billion Yen

"B/S: Producer"=

"Demand Deposits (Producer)"  
+ "Inventory (Producer)"  
+ "Capital (PP&E) (Producer)"  
- "Loans from Banks (Producer)"  
- "Share Capital (Producer)"  
- "Retained Earnings (Producer)"

Units: Billion Yen

"Base Money (-1)"=

DELAY FIXED(Base Money, 1, Base Money)

Units: Billion Yen

Base Money Growth Rate=

ZIDZ(Base Money - "Base Money (-1)" ,

"Base Money (-1)"

)

\* Growth Unit

Units: 1/Year

C Ratio Change Period=

0

Units: Year [0,70,1]

C Ratio Change Time=

1980

Units: Year [1980,2050,1]

C Ratio Max=

0.02

Units: Dmnl [0,0.05,0.001]

C Ratio Min=

0

Units: Dmnl [0,0.05,0.001]

C Ratio Seed=

10

Units: Dmnl [1,100,1]

"Call Rate (nominal) (%)"=

"Call Rate (nominal)" \* "Conversion to %"

Units: Percent/Year

"Call Rate (nominal)"= INTEG (

Change in Call Rate,

"INITIAL Call Rate (nominal)")

Units: 1/Year

Call Rate Elasticity Change Period=

0

Units: Year [0,50,1]

Call Rate Elasticity Change Time=

2000

Units: Year [1980,2050,1]

"Capital (PP&E) (Producer)"= INTEG (

"Capital Investment (Producer)"-"Depreciation (Capital)",

"INITIAL Capital (PP&E) (Producer)")

Units: Billion Yen

Capital completion=

Capital under Construction / Construction Period

Units: Billion YenReal/Year

"Capital Investment (Producer) (-1)"=

DELAY FIXED("Capital Investment (Producer)", 1, "Capital Investment (Producer)")

)

Units: Billion Yen/Year

"Capital Investment (Producer) (1980-2013)"=  
"Private&Public Capital Investment (1980-2013)"  
+ "Government Capital Investment (1980-2013)"

Units: Billion Yen/Year

"Capital Investment (Producer) Growth Rate (%)"=  
"Capital Investment (Producer) Growth Rate" \* "Conversion to %"

Units: Percent/Year

"Capital Investment (Producer) Growth Rate"=  
ZIDZ("Capital Investment (Producer)" - "Capital Investment (Producer) (-1)"

,

"Capital Investment (Producer) (-1)"

)

\* Growth Unit

Units: 1/Year

"Capital Investment (Producer)"=  
IF THEN ELSE("Demand Deposits (Producer)"\*per Year <= Desired  
Investment,

"Demand Deposits (Producer)"\*per Year ,

Desired Investment

)

Units: Billion Yen/Year

IF production sector does not have enough liquidity to cover  
desired investment, THEN use all the available liquidity to  
cover the desired capital investment. ELSE spend the desired



amount only.

"Capital PP&E (1980-2014)"

Units: Billion Yen

"Capital PP&E (real)"= INTEG (  
Capital completion-"Depreciation (real)",  
"INITIAL Capital PP&E (real)")

Units: Billion YenReal

"Capital Shares (Household)"= INTEG (  
"Investment in Shares (Household)",  
"INITIAL Shares (Household)")

Units: Billion Yen

Capital Shares Newly Issued=  
Newly Issued Capital Shares

Units: Billion Yen/Year

Capital under Construction= INTEG (  
"Investment (real)"-Capital completion,  
INITIAL Capital under Construction)

Units: Billion YenReal

"Capital-Output Ratio"=  
"Capital PP&E (real)"  
/ Full Capacity GDP

Units: Year

The higher, the less capital output productivity as an input.

"Cash (Household) (1980-2013)"

Units: Billion Yen

"Cash (Household)"= INTEG (  
Cash Demand,  
"INITIAL Cash (Household)")

Units: Billion Yen

Cash Demand=

IF THEN ELSE(SWITCH Cash=0 ,  
("Desired Cash (Household)" - "Cash (Household)") / Time to  
Withdraw Cash  
,  
( Currency Ratio \* "Demand Deposits (Household)" - "Cash  
(Household)"  
)  
/ Time to Withdraw Cash  
)

Units: Billion Yen/Year

on false = returns an original equation used in flow approach  
model.

Cash Flow from Financing Activities=

Newly Issued Capital Shares  
+ "Borrowings (Producer)"  
-"Debt Finance Expenditures (Producer)"  
- "Equity Finance Expenditures (Producer)"

Units: Billion Yen/Year

Cash Flow from Investing Activities=

- Desired Investment

Units: Billion Yen/Year

Cash Flow from Operating Activities=

Sales - "Payments (Producer)"

Units: Billion Yen/Year

Cash inflow=

0

Units: Billion Yen/Year

Cash outflow=

IF THEN ELSE( "Vault Cash (Banks)"<=0, 0, Cash Demand)

Units: Billion Yen/Year

Change in AD Forecasting=

( "Aggregate Demand (real)" - Aggregate Demand Forecasting )  
/Time to Adjust Forecasting

Units: Billion YenReal/(Year\*Year)

"Change in AD Forecasting (Long-run)"=

( "Aggregate Demand (real)" - "Aggregate Demand Forecasting (Long-run)" )  
/ "Time to Adjust Forecasting (Long-run)"

Units: Billion YenReal/Year/Year

Change in Adaptive PR=

Discrepancies from Prime Rate/Adjustment Time of Prime Rate

Units: 1/(Year\*Year)

Change in Call Rate=

(Desired Call Rate - "Call Rate (nominal)" )  
/ Delay Time of Call Rate Change

Units: 1/Year/Year

Change in Corporate Tax Rate=  
0

Units: Dmnl [-0.05,0.05,0.005]

Change in elasticity of call rate=  
0

Units: Dmnl [-0.09,0.4,0.001]

Change in Excise Tax Rate=  
0

Units: Dmnl [-0.05,0.15,0.005]

Change in Expenditure=  
"Growth-dependent Expenditure" \* "GDP (real) Growth Rate"

Units: Billion Yen/Year/Year

Change in Government Expenditure=  
0

Units: Billion Yen/Year [-10000,30000,1000]

Change in Income Tax Rate=  
0

Units: Dmnl [-0.1,0.1,0.01]

Change in Interest Sensitivity=  
0

Units: Dmnl [-0.56,0.44,0.01]

"Change in Lump-sum Taxes"=

0

Units: Billion Yen/Year [-5000,20000,1000]

Change in Price=

(Desired Price - Price Level )/ Delay Time of Price Change

+ "Cost-push (Wage) Coefficient" \* Wage Rate Change

Units: (Yen/YenReal)/Year

Change in Wage Rate=

(Desired Wage Rate - Wage Rate)

/ Delay Time of Wage Change

Units: Yen/(Year\*Person)/Year

Changes in Adaptive IR=

Discrepancies from Inflation Rate/Adjustment Time of IR

Units: 1/Year/Year

"Changes in Inventory (1980-2013)"

Units: Dollar/Year

"Checking F/F failure in demand deposits"=

("GDP (real)" + "Inventory (real)"\*per Year)

- "Aggregate Demand (real)"

Units: Billion YenReal/Year

Sales, which is one of the inflow in Demand Deposits (Producer),

is = Sales(real)\*Price. On the other hand, Government

Expenditures, which is one of the inflow into Demand

Deposit(Banks), is = Government Expenditure (real)\*Price. If  
There are discrepancies in one of the componet in Aggregate  
Demand (real), there wil be discrepancies in F/F: Demand  
Deposits.

college attendance ratio=

0.603683

Units: Dmnl

Maximum payoff value

College graduation=

College Students

/ Average college schooling time

Units: thousand people/Year

College Students= INTEG (

"HS graduation (going to college)" - College graduation,  
INITIAL College Students)

Units: thousand people

"College Students (1980-2014)"

Units: thousand people

constant total fertility=

1.5

Units: Dmnl

Construction Period=

2

Units: Year [0,10,0.1]

Consumption=

(Basic consumption

+ Marginal Propensity to Consume \* Disposable Income )

\* Effect on Consumption

Units: Billion Yen/Year

Assuming the Keynes Consumption Function. Statistically, Household's final consumption expenditure. Examples include food, rent, jewelry, gasoline and medical expenses, but NOT the purchase of new housing.

"Consumption (-1)"=

DELAY FIXED( Consumption, 1, Consumption)

Units: Billion Yen/Year

"Consumption (1980-2013)"

Units: Billion Yen/Year

"Consumption (nominal) Growth Rate (%)"=

"Consumption (nominal) Growth Rate" \* "Conversion to %"

Units: Percent/Year

"Consumption (nominal) Growth Rate"=

ZIDZ( Consumption-"Consumption (-1)", "Consumption (-1)")

\* Growth Unit

Units: 1/Year

"Conversion from Year to %"=

1

Units: Year

"Conversion to %"=

100

Units: Percent

"Corporate lending (Banks)"=

(1-SWITCH Reserve Constraint)\*IF THEN ELSE( SWITCH Max Loanable Funds=0 ,

"Desired Borrowing from Banks (Producer)"

- "Desired Borrowing from Banks (Producer)" \* (Lending

Disapproval Ratio

\*PULSE(Credit Crunch Time, Credit Crunch Period) ) ,

MIN( Maximum Loanable Funds , "Desired Borrowing from

Banks (Producer)"

- "Desired Borrowing from Banks (Producer)"

\* (Lending Disapproval Ratio

\*PULSE(Credit Crunch Time, Credit Crunch Period) ) )

)

+SWITCH Reserve Constraint\*MIN( "Reserves (Banks)"\*per Year, "Desired Borrowing from Banks (Producer)"

- "Desired Borrowing from Banks (Producer)"

\* (Lending Disapproval Ratio

\*PULSE(Credit Crunch Time, Credit Crunch Period) ) )

Units: Billion Yen/Year

Corporate Tax=

Profits before Tax \* Corporate Tax Rate

Units: Billion Yen/Year

Corporate Tax Rate=



"Corporate Tax Rate (base)" + STEP(Change in Corporate Tax Rate,  
Starting Time for Fiscal Policy)

Units: Dmnl [0,0.4,0.01]

Original Flow approach model = 0.3

"Corporate Tax Rate (base)"=

0.3

Units: Dmnl [0.1,0.3,0.01]

"Cost-push (Wage) Coefficient"=

0

Units: Yen/YenReal [0,0.5,0.01]

Credit Crunch Period=

3

Units: Year [1,10,1]

Credit Crunch Time=

1995

Units: Year [1980,2010,1]

Currency in Circulation=

"Currency Outstanding (Central Bank)" - "Vault Cash (Banks)"

Units: Billion Yen

"Currency Outstanding (1980-2013)"

Units: Billion Yen

"Currency Outstanding (Central Bank)"= INTEG (  
Adjusting Vault Cash,

"INITIAL Currency Outstanding (Central Bank)"

Units: Billion Yen

Currency Ratio=

IF THEN ELSE( SWITCH Currency Ratio Random Walk=0,  
0.01 + STEP(C Ratio Change, C Ratio Change Time ) ,  
C Ratio Change\*PULSE(C Ratio Change Time, C Ratio Change Period) +  
RANDOM UNIFORM  
(C Ratio Min, C Ratio Max, C Ratio Seed  
)  
)

Units: Dmnl

Currency Ratio = Currency in Circulation / Deposits Outstanding

In the original flow approach, it was defined as follows;

Currency Ratio Table ( Interest Rate on Demand Deposits \*

Unit Year) + STEP(Change in Currency Ratio, Time for

Change in Currency Ratio) IF THEN ELSE( SWITCH

Currency Ratio Random

Walk=0, 0.01 + STEP(C Ratio Change, C Ratio Change

Time ) ,

STEP( C Ratio Change, C Ratio Change Time) + RANDOM

UNIFORM(C Ratio Min, C Ratio Max, C Ratio Seed) )

Currency Ratio Table(

[(0,0)-(0.1,1)],(0,1),(0.001,0.98),(0.005,0.78),(0.015,0.5),(0.03,0.2),(0.0501149,0  
) ,(0.1,0))

Units: Dmnl

"deaths (1980-2013)"

Units: thousand people/Year

deaths 0 to 14=

Population 0 to 14 \* mortality 0 to 14

Units: thousand people/Year

deaths 15 to 44=

Population 15 to 44 \* mortality 15 to 44

Units: thousand people/Year

deaths plus 65=

Population plus 65 \* mortality plus 65

Units: thousand people/Year

"Debt (Banks)"= INTEG (

"Borrowing (Banks)"-"Debt Redemption (Banks)",

"INITIAL Debt (Banks)")

Units: Billion Yen

"Debt (Government)"= INTEG (

Government Securities Newly Issued-"Debt Redemption (Government)",

"INITIAL Debt (Government)")

Units: Billion Yen

"Debt Finance Expenditures (Producer)"=

"Debt Redemption (Producer)" + "Interest paid by Producer (Banks)"

Units: Billion Yen/Year

"Debt period (Banks)"=

1

Units: Year [0.5,20,0.5]

"Debt Period (Government)"=

10

Units: Year

"Debt Period (Producer)"=

15

Units: Year [1,80,1]

"Debt Redemption (Banks)"=

"Debt (Banks)" / "Debt period (Banks)"

Units: Billion Yen/Year

"Debt Redemption (Government)"=

"Debt (Government)" / "Debt Period (Government)"

Units: Billion Yen/Year

"Debt Redemption (Household)"=

0

Units: Billion Yen/Year

"Debt Redemption (Producer)"=

"Loans from Banks (Producer)"

/ "Debt Period (Producer)"

Units: Billion Yen/Year

Decrease in Reserves=

Open Market Sale

Units: Billion Yen/Year

Delay Time of Call Rate Change=

1

Units: Year [0.1,7,0.1]

Delay Time of Price Change=

10

Units: Year [5,10,1]

Delay Time of Wage Change=

5

Units: Year [1,10,1]

"Demand Deposits (Banks) (1980-2013)"

Units: Billion Yen

"Demand Deposits (Banks)"= INTEG (

"Deposits inflow (Banks)"-"Deposits outflow (Banks)"-"Saving  
(Household)", "INITIAL Demand Deposits (Banks)")

Units: Billion Yen

"Demand Deposits (Household)"= INTEG (

"Borrowings (Household)"+"Income (Household)"+"Redemption of Gov Bonds  
(Household)" - Cash Demand-Consumption - "Interest paid by Household  
(Banks)"-"Investment in Government Security (Household)" - "Investment in Shares  
(Household)" - "Saving (Household)"-"Tax Payments (Household)",

"INITIAL Demand Deposits (Household)")

Units: Billion Yen

"Demand Elasticity of Call Rate (base)"=

0.1

Units: Dmnl [0.001,1,0.001]

"Deposits (Government)"= INTEG (  
    "Borrowings (Government )"+Tax Revenues+Transfers from Central  
    Bank-"Debt Redemption (Government)"  
    -Government Expenditures-"Interest Payment (Government)",  
    "INITIAL Deposits (Government)")

Units: Billion Yen

"Desired Borrowing (Banks)"=  
    MAX(0, -(Reserves Flow Deficit) )"SWITCH Reserve Supply (Lending  
    Facility)"

Units: Billion Yen/Year

"Desired Borrowing from Banks (Producer)"=  
    Desired Financing \*(1-Direct Financing Ratio)

Units: Billion Yen/Year

Desired Call Rate=  
    "Call Rate (nominal)" \* Effect on Call Rate

Units: 1/Year

"Desired Capital (real)"=  
    (ZIDZ(  
        Exponent on Capital  
        \* ( 1 - Excise Tax Rate )  
        \* "Aggregate Demand Forecasting (Long-run)" ,  
        (Prime Rate \* Interest Sensitivity + Depreciation Rate)  
    )\*(1 - SWITCH Prime Rate))  
    +

$$\begin{aligned}
 & \text{(ZIDZ(} \\
 & \quad \text{Exponent on Capital} \\
 & \quad \quad * ( 1 - \text{Excise Tax Rate} ) \\
 & \quad \quad * \text{"Aggregate Demand Forecasting (Long-run)" ,} \\
 & \quad \text{"Adaptive Prime Rate (real)"* Interest Sensitivity + Depreciation Rate} \\
 & \text{)} \\
 & \quad \text{)*SWITCH Prime Rate )}
 \end{aligned}$$

Units: Billion YenReal

$$\text{"Desired Cash (base)"=}$$

500

Units: Billion Yen [0,15000,500]

$$\text{"Desired Cash (Household)"=}$$

"Desired Cash (base)"

+ SWITCH Desired Cash\*("Demand Deposits (Household)"\*Desired Currency

Ratio

)

Units: Billion Yen [0,10000,500]

$$\text{"Actual Currency Ratio (M2)"=}$$

ZIDZ( Currency in Circulation, Total Deposits Outstanding )

Units: Dmnl

$$\text{"Actual Reserve Ratio (M1)"=}$$

ZIDZ("Reserves (Central Bank)", "Demand Deposits (Banks)" )

Units: Dmnl

$$\text{"Actual Reserve Ratio (M2)"=}$$

ZIDZ("Reserves (Central Bank)", Total Deposits Outstanding )

Units: Dmnl

"Base Money Growth Rate (%)"=

$$\text{Base Money Growth Rate} * \text{"Conversion to \%"}"$$

Units: Percent/Year

"Consumption (real) (-1)"=

$$\text{DELAY FIXED( "Consumption (real)", 1, "Consumption (real)" )}$$

Units: Billion YenReal/Year

"Consumption (real) Growth Rate (%)"=

$$\text{"Consumption (real) Growth Rate"} * \text{"Conversion to \%"}"$$

Units: Percent/Year

"Consumption (real) Growth Rate"=

$$\text{ZIDZ( ("Consumption (real)" - "Consumption (real) (-1)" ), "Consumption (real) (-1)" ) * Growth Unit}$$

Units: 1/Year

"Consumption (real)"=

$$\text{ZIDZ(Consumption, Price Level)}$$

Units: Billion YenReal/Year

deaths 45 to 64=

$$\text{Population 45 to 64} * \text{mortality 45 to 64}$$

Units: thousand people/Year

Delay Time for Prime Rate Smoothing=

3



Units: Year [1,5,1]

"Demand Deposits (Household) (1981-2013)"

Units: Billion Yen

"Demand Deposits (Producer) (1980-2013)"

Units: Billion Yen

"Deposit Flow (Cash Flow)"=

Cash Flow from Operating Activities  
+ Cash Flow from Investing Activities  
+ Cash Flow from Financing Activities

Units: Billion Yen/Year

"Deposits inflow (Banks)"=

"Wages (Banks)"  
+ "Corporate lending (Banks)"  
+ Cash inflow  
+ Government Expenditures  
+ "Interest Income (Household)"  
+ "Redemption of Gov Bonds (Household)"  
+ "Household Lending (Banks)"  
+ "Wages (Central Bank)"

Units: Billion Yen/Year

"Deposits outflow (Banks)"=

"Debt Redemption (Producer)"  
+ Cash outflow  
+ "Interest paid by Household (Banks)"  
+ "Interest paid by Producer (Banks)"

- + Tax Revenues from Producer
- + Tax Revenues from Households
- + "Investment in Government Security (Household)"

Units: Billion Yen/Year

"Depreciation (1980-2014)"

Units: Billion Yen/Year

"Depreciation (Capital)"=

$$\text{"Depreciation (real)" * Price Level}$$

Units: Billion Yen/Year

"Depreciation (real)"=

$$\text{"Capital PP\&E (real)" * Depreciation Rate}$$

Units: Billion YenReal/Year

Depreciation Rate=

$$0.03$$

Units: 1/Year

"Desired Capital-Output Ratio"=

$$\text{ZIDZ( Exponent on Capital * ( 1- Excise Tax Rate ) , ( Prime Rate + Depreciation Rate ) )}$$

Units: Year

Desired Currency Ratio=

$$0.01$$

Units: Dmnl [0,0.1,0.005]

Desired Financing=

SWITCH Desired Financing\*IF THEN ELSE( "Demand Deposits  
(Producer)"\*per Year

- "Liquidity Deficit (Cash Flow Deficit)"<=

0,

MAX(-"Liquidity Deficit (Cash Flow Deficit)", 0) ,

0

)

+(1-SWITCH Desired Financing)\*MAX(-"Liquidity Deficit (Cash Flow Deficit)",

0) \* Desired Financing Ratio

Units: Billion Yen/Year

Desired Financing Ratio=

1

Units: Dmnl [0.5,1,0.01]

Desired Inventory=

Aggregate Demand Forecasting \* Normal Inventory Coverage

Units: Billion YenReal

Desired Inventory Investment=

( Desired Inventory - "Inventory (real)" )

/ Time to Adjust Inventory

Units: Billion YenReal/Year

Desired Investment=

"Desired Investment (real)" \* Price Level

Units: Billion Yen/Year

"Desired Investment (real)"=

$$\begin{aligned} & \text{MAX}(0, ( \text{"Desired Capital (real)" } - \text{"Capital PP\&E (real)" } ) ) \\ & \quad / \text{Time to Adjust Capital} \\ & \quad + \text{"Depreciation (real)"} \end{aligned}$$

Units: Billion YenReal/Year

Desired Labor=

$$\begin{aligned} & \text{ZIDZ}( \\ & \quad ( 1 - \text{Labor Market Flexibility} * \text{"GDP Gap Ratio (Capacity} \\ & \quad \text{Idleness)" } ) \\ & \quad * ( \text{Exponent on Labor} * ( 1 - \text{Excise Tax Rate } ) \\ & \quad * \text{Price Level} \\ & \quad * \text{"Desired Output (real)" } ) , \\ & \quad \text{Expected Wage Rate} \\ & \quad ) * ( 1 - \text{SWITCH GDP Gap Reverse} ) \\ & + \\ & \text{ZIDZ}( ( 1 - \text{Labor Market Flexibility} * \text{"GDP Gap Ratio (Reverse)" } ) \\ & \quad * ( \text{Exponent on Labor} * ( 1 - \text{Excise Tax Rate } ) \\ & \quad * \text{Price Level} \\ & \quad * \text{"Desired Output (real)" } ) , \\ & \quad \text{Expected Wage Rate} \\ & \quad ) * \text{SWITCH GDP Gap Reverse} \end{aligned}$$

Units: thousand people

"Desired Output (real)"=

$$\text{MAX}( 0, \text{Aggregate Demand Forecasting} + \text{Desired Inventory Investment} )$$

Units: Billion YenReal/Year

Desired Price=

$$\text{Price Level} * \text{Effect on Price}$$

Units: Yen/YenReal

"Desired Vault Cash (Banks)"=  
5000

Units: Billion Yen [0,5000,500]

Desired Wage Rate=  
Wage Rate \* Effect on Wage

Units: Yen/(Year\*Person)

Direct Financing Ratio=  
0

Units: Dmnl [0,1,0.01]

Discount Lending Rate=  
"Call Rate (nominal)"  
+ STEP(Discount Rate Premium, Discount Rate Change Time)

Units: 1/Year

Discount Rate Adjustment=  
STEP(Discount Rate Change , Discount Rate Change Time )

Units: 1/Year

Discount Rate Change=  
0

Units: 1/Year [-0.008,0.03,0.001]

Discount Rate Change Time=  
10

Units: Year [0,50,1]

Discount Rate Premium=

0.005

Units: 1/Year [0,0.02,0.005]

"Discount Window Lending (Central Bank)"=

"Desired Borrowing (Banks)"\*Window Guidance

+ Lending by Central Bank\*PULSE(Lending Time, Lending Period)

Units: Billion Yen/Year

Discrepancies from Inflation Rate=

Inflation Rate-Inflation Rate Expectation

Units: 1/Year

Discrepancies from Prime Rate=

"Prime Rate (real)" - "Adaptive Prime Rate (real)"

Units: 1/Year

Disposable Income=

"Income (Household)" - "Tax Payments (Household)"

Units: Billion Yen/Year

Dividend Ratio in Profits=

0.8

Units: Dmnl

Dividends=

Profits \* Dividend Ratio in Profits

Units: Billion Yen/Year

Effect on Call Rate=

$$\text{SWITCH Call Rate} + (1 - \text{SWITCH Call Rate}) * (\text{ZIDZ}(1, \text{Excess Reserves Ratio})^{\text{Elasticity of Call Rate}})$$

Units: Dmnl

Effect on Consumption=

$$1/(\text{Price Level}/\text{INITIAL Price Level})^{\text{Price Elasticity of Consumption}}$$

Units: Dmnl

Effect on Price=

$$1/((1 - \text{Weight of Inventory Ratio}) * \text{Production Ratio} + \text{Weight of Inventory Ratio} * \text{Inventory Ratio})^{\text{Output Ratio Elasticity (Effect on Price)}}$$

Units: Dmnl

Effect on Wage=

$$1/\text{Labor Ratio}^{\text{Labor Ratio Elasticity (Effect on Wage)}}$$

Units: Dmnl

Elasticity of Call Rate=

$$\text{"Demand Elasticity of Call Rate (base)"}$$

+

$$\text{Change in elasticity of call rate} * \text{PULSE}(\text{Call Rate Elasticity Change Time, Call Rate Elasticity Change Period})$$

Units: Dmnl

Employed Labor= INTEG (

$$\text{Net employment} + \text{new employment} - \text{"retiring (employed)"},$$

INITIAL Employed Labor)

Units: thousand people

"Employed Labor (1980-2013)"

Units: thousand people

"Employed Labor (Banks)"=

Employed Labor \* "Employed Labor Ratio (Banks)"

Units: thousand people

"Employed Labor (Central Bank)"=

Employed Labor \* "Employed Labor Ratio (Central Bank)"

Units: thousand people

"Employed Labor (Producer)"=

Employed Labor \* "Employed Labor Ratio (Producer)"

Units: thousand people

Employed Labor Ratio=

ZIDZ(Employed Labor, Employed Labor + Unemployed Labor)

Units: Dmnl

"Employed Labor Ratio (Banks)"=

1 - "Employed Labor Ratio (Producer)"

- "Employed Labor Ratio (Central Bank)"

Units: Dmnl [0,1]

"Employed Labor Ratio (Central Bank)"=

0.0005

Units: Dmnl



"Employed Labor Ratio (Producer)"=

0.95

Units: Dmnl [0,1,0.01]

Arbitrary chose. In original model, it is 1.

"Equity Finance Expenditures (Producer)"=

Dividends

Units: Billion Yen/Year

Excess Reserves=

"Reserves (Banks)" - Required Reserves

Units: Billion Yen

Excess Reserves Ratio=

ZIDZ("Reserves (Banks)", Required Reserves)

Units: Dmnl

Supply-Demand Relationship in Central Bank Reserves

Excise Tax Rate=

0.05

+ STEP ( Change in Excise Tax Rate ,  
Starting Time for Fiscal Policy )

Units: Dmnl

Expected Wage Rate=

Wage Rate \* ( 1+ Inflation Rate / per Year )

Units: Yen/(Year\*Person)

Exponent on Capital=

0.4

Units: Dmnl [0.35,0.45,0.005]

Original flow approach model value = 0.4

Exponent on Labor=

0.5

Units: Dmnl [0,5,0.05]

Original value = 0.5

"F/F: Currency Outstanding"=

"Cash (Household)"

+ "Vault Cash (Banks)"

- "Currency Outstanding (Central Bank)"

Units: Billion Yen

"F/F: Debt (Banks)"=

"Loan (Central Bank)"

- "Debt (Banks)"

Units: Billion Yen

"F/F: Debt Redemption (Government)"=

"Redemption of Gov Bonds (Banks)"

+ "Redemption of Gov Bonds (Central Bank)"

+ "Redemption of Gov Bonds (Household)"

- "Debt Redemption (Government)"

Units: Billion Yen/Year

"F/F: Demand Deposits"=

"Demand Deposits (Household)"

+ "Demand Deposits (Producer)"

- "Demand Deposits (Banks)"

Units: Billion Yen

"F/F: Gov Bonds Issuance"=

"Investment in Government Security (Banks)"

+ "Investment in Government Security (Household)"

- Government Securities Newly Issued

Units: Billion Yen/Year

"F/F: Government Debt"=

"Government Bonds (Banks)"

+ "Government Bonds (Central Bank)"

+ "Government Bonds (Household)"

- "Debt (Government)"

Units: Billion Yen

"F/F: Government Deposits"=

"Deposits (Government)" - "Government Deposits (Central Bank)"

Units: Billion Yen

"F/F: Loan (Banks)"=

"Loans from Banks (Household)"

+ "Loans from Banks (Producer)"

- "Loans Receivable (Banks)"

Units: Billion Yen

"F/F: Loan (Central Bank)"=

"Loan (Central Bank)"

- "Debt (Banks)"

Units: Billion Yen

"F/F: Reserves"=

"Reserves (Banks)"  
- "Reserves (Central Bank)"

Units: Billion Yen

"F/F: Share Capitals"=

"Capital Shares (Household)"  
- "Share Capital (Producer)"

Units: Billion Yen

"F/F: Time Deposits"=

"Savings Deposits (Household)"  
- "Time Deposits (Banks)"

Units: Billion Yen

Fiscal Deficit=

IF THEN ELSE(Tax Revenues  
< Government Expenditures  
+ "Interest Payment (Government)",  
Government Expenditures  
+ "Interest Payment (Government)"  
- Tax Revenues ,  
0 )

Units: Billion Yen/Year

Fiscal Deficit to GDP Ratio=

ZIDZ(Fiscal Deficit, "GDP (Revenues)")

Units: Dmnl

"Fiscal Deficit to GDP Ratio (%)"=

Fiscal Deficit to GDP Ratio \* "Conversion to %"

Units: Percent

Full Capacity GDP=

EXP( Technological Change \* (Time - INITIAL TIME)) \* Initial Potential GDP

\* POWER ("Capital PP&E (real)" / "Initial Capital (real)",  
Exponent on Capital )

\* POWER (Employed Labor / Initial Labor Force,  
Exponent on Labor )

Units: Billion YenReal/Year

"GDP (nominal) (-1)"=

DELAY FIXED("GDP (Revenues)", 1, "GDP (Revenues)")

Units: Billion Yen/Year

"GDP (nominal) (1980-2014)"

Units: Billion Yen/Year

"GDP (nominal) Growth Rate (%)"=

"GDP (nominal) Growth Rate" \* "Conversion to %"

Units: Percent/Year

"GDP (nominal) Growth Rate"=

ZIDZ( ("GDP (Revenues)"-"GDP (nominal) (-1)" ) , "GDP (nominal) (-1)" )  
\* Growth Unit

Units: 1/Year

"GDP (nominal)"=

"GDP (Revenues)"

Units: Billion Yen/Year

"GDP (real) (-1)"=

DELAY FIXED("GDP (real)", 1, "GDP (real)")

Units: Billion YenReal/Year

"GDP (real) Growth Rate (%)"=

"GDP (real) Growth Rate" \* "Conversion to %"

Units: Percent/Year

"GDP (real) Growth Rate"=

XIDZ("GDP (real)" - "GDP (real) (-1)", "GDP (real) (-1)", 0)

\* Growth Unit

Units: 1/Year

"GDP (real)"=

MIN( Full Capacity GDP, "Desired Output (real)" )

Units: Billion YenReal/Year

"GDP (Revenues)"=

"GDP (real)" \* Price Level

Units: Billion Yen/Year

"GDP Gap Ratio (%)"=

"GDP Gap Ratio (Capacity Idleness)" \* "Conversion to %"

Units: Percent

"GDP Gap Ratio (Capacity Idleness)"=

("GDP (real)" - Potential GDP )

/ Potential GDP

Units: Dmnl

An indicator of the difference between the actual output of an economy and the maximum potential output of the economy, resulting from the failure to create sufficient jobs for all those willing to work. Formerly,  $(\text{Potential GDP} - \text{"GDP (real)"}) / \text{Potential GDP}$

"GDP Gap Ratio (Reverse)"=  
 $(\text{Potential GDP} - \text{"GDP (real)"}) / \text{Potential GDP}$

Units: Dmnl

"Gov Bond Holding Ratio (Banks)"=  
 $\text{"Government Bonds (Banks)" } / (\text{"Government Bonds (Household)" } + \text{"Government Bonds (Banks)"})$

Units: Dmnl

"Gov Bonds Holding Ratio in Issuance (Household)"=  
 $\text{"Government Bonds (Household)" } / (\text{"Government Bonds (Household)" } + \text{"Government Bonds (Banks)"})$

Units: Dmnl

"Gov Bonds Holding Ratio in Redemption (Banks)"=  
 $\text{"Government Bonds (Banks)" } / (\text{"Government Bonds (Household)" } + \text{"Government Bonds (Banks)" } + \text{"Government Bonds (Central Bank)"})$

Units: Dmnl

"Gov Bonds Holding Ratio in Redemption (Central Bank)"=

"Government Bonds (Central Bank)" /  
 ("Government Bonds (Household)" + "Government Bonds (Banks)" +  
 "Government Bonds (Central Bank)"  
 )

Units: Dmnl

"Gov Bonds Holding Ratio in Redemption (Household)"=  
 "Government Bonds (Household)" /  
 ("Government Bonds (Household)" + "Government Bonds (Banks)" +  
 "Government Bonds (Central Bank)"  
 )

Units: Dmnl

Government Bonds are equally repaid back to its holders.

"Gov Debt Growth Rate (%)"=  
 ZIDZ("Debt (Government)"-"Government Debt (-1)", "Government Debt  
 (-1)")\*"Conversion to %"

Units: Percent

"Government Bonds (Banks) (1980-2013)"

Units: Billion Yen

"Government Bonds (Banks)"= INTEG (  
 "Investment in Government Security (Banks)"+"Open Market Sale (Banks  
 Purchase)"

-"Open Market Purchase (Banks Sale)"-"Redemption of Gov Bonds (Banks)",

"INITIAL Government Bonds (Banks)"

Units: Billion Yen

"Government Bonds (Central Bank) (1980-2013)"



Units: Billion Yen

"Government Bonds (Central Bank)"= INTEG (  
Open Market Purchase-Open Market Sale-"Redemption of Gov Bonds (Central  
Bank)"

,

"INITIAL Government Bonds (Central Bank)")

Units: Billion Yen

"Government Bonds (Household) (1981-2013)"

Units: Billion Yen

"Government Bonds (Household)"= INTEG (  
"Investment in Government Security (Household)"-"Redemption of Gov Bonds  
(Household)"

,

"INITIAL Government Bonds (Household)")

Units: Billion Yen

"Government Bonds Outstanding (1980-2016)"

Units: Billion Yen

"Government Capital Investment (1980-2013)":INTERPOLATE:

Units: Billion Yen/Year

"Government Debt (-1)"=

DELAY FIXED( "Debt (Government)", 1, "Debt (Government)")

Units: Billion Yen

Government Debt to GDP Ratio=

ZIDZ("Debt (Government)", "GDP (Revenues)")

Units: Year

"Government Debt to GDP Ratio (%)"=

Government Debt to GDP Ratio / "Conversion from Year to %"  
\* "Conversion to %"

Units: Percent

Government Deficit=

IF THEN ELSE(Tax Revenues + Transfers from Central Bank  
< Government Expenditures  
+ "Debt Redemption (Government)"  
+ "Interest Payment (Government)" ,

Government Expenditures  
+ "Debt Redemption (Government)"  
+ "Interest Payment (Government)"  
- Tax Revenues  
- Transfers from Central Bank ,

0 )

Units: Billion Yen/Year

Government Deficit to GDP Ratio=

ZIDZ(Government Deficit, "GDP (Revenues)")

Units: Dmnl

"Government Deficit to GDP Ratio (%)"=

Government Deficit to GDP Ratio \* "Conversion to %"

Units: Percent

"Government Deposits (Central Bank)"= INTEG (

"Reserves Transfer (CB-Gov)" + Transfers to the Treasury - Interest Paid  
 by the Government - "Redemption of Gov Bonds (Central Bank)"  
 - "Reserves Transfer (Gov-CB)",  
 "INITIAL Government Deposits (Central Bank)"

Units: Billion Yen

"Government Expenditure (nominal) Growth Rate (%)" =

"Government Expenditure (nominal) Growth Rate" \* "Conversion to %"

Units: Percent/Year

"Government Expenditure (nominal) Growth Rate" =

ZIDZ(Government Expenditures - "Government Expenditures (-1)",

"Government Expenditures (-1)" ) \* Growth Unit

Units: 1/Year

"Government Expenditure (real) (-1)" =

DELAY FIXED("Government Expenditures (real)", 1, "Government  
 Expenditures (real)" )

Units: Billion YenReal/Year

"Government Expenditure (real) Growth Rate (%)" =

"Government Expenditure (real) Growth Rate" \* "Conversion to %"

Units: Percent/Year

"Government Expenditure (real) Growth Rate" =

ZIDZ("Government Expenditures (real)" - "Government Expenditure  
 (real) (-1)", "Government Expenditure (real) (-1)" ) \* Growth Unit

Units: 1/Year

Government Expenditures =

IF THEN ELSE ( SWITCH Gov Expenditure > 0,  
 "Revenue-dependent Expenditure" ,  
 MAX ( 0,  
 "Growth-dependent Expenditure" ) )  
 + STEP ( Change in Government Expenditure ,  
 Starting Time for Fiscal Policy )

Units: Billion Yen/Year

The sum of government expenditures on final goods and services. It includes salaries of public servants(school teachers, police officers etc), construction of social infrastructures, capital depreciation, purchases of weapons for the military. It does NOT include any transfer payments, such as social security or unemployment benefits.

"Government Expenditures (-1)"=

DELAY FIXED(Government Expenditures, 1, Government Expenditures)

Units: Billion Yen/Year

"Government Expenditures (1980-2013)"

Units: Billion Yen/Year

"Government Expenditures (real)"=

ZIDZ (Government Expenditures, Price Level)

Units: Billion YenReal/Year

Government Securities Newly Issued=

Government Deficit

Units: Billion Yen/Year

"Government Short-Term Securities (1980-2016)":INTERPOLATE:

Units: Billion Yen

"Gross Domestic Expenditure (real)"=  
"Aggregate Demand (real)"  
+ Inventory Investment

Units: Billion YenReal/Year

Growth Unit=

1

Units: 1/Year [1,1]

"Growth-dependent Expenditure"= INTEG (  
Change in Expenditure,  
Base Expenditure)

Units: Billion Yen/Year

High School Students= INTEG (  
maturation 14 to 15 - "HS graduation (going to college)"  
- "HS graduation (not going to college)",  
INITIAL High School)

Units: thousand people

"High School Students (1980-2014)"

Units: thousand people

Source: Ministry of Education and Science

high schooling time=

3

Units: Year

"High-Powered Money"=

Currency in Circulation  
+ "Reserves (Central Bank)"

Units: Billion Yen

"Household Lending (Banks)"=  
0

Units: Billion Yen/Year

"HS graduation (going to college)"=  
( High School Students \* college attendance ratio )  
/ high schooling time

Units: thousand people/Year

"HS graduation (not going to college)"=  
(High School Students \* (1 - college attendance ratio))  
/ high schooling time

Units: thousand people/Year

"Income (Household)"=  
Wage Income  
+ "Income from Financial Investment (Household)"

Units: Billion Yen/Year

"Income from Financial Investment (Household)"=  
"Interest Income (Household)"  
+ Dividends

Units: Billion Yen/Year

Income Tax=  
"Income (Household)" \* Income Tax Rate

Units: Billion Yen/Year

Income Tax Rate=

$0.12 + \text{Change in Income Tax Rate} * \text{PULSE}(\text{Income Tax Rate Change Time},$   
 $\text{Income Tax Rate Change Period}$   
 $)$

Units: Dmnl

Previously,  $0.12 + \text{STEP}(\text{Change in Income Tax Rate}, \text{Starting Time}$   
 $\text{for Fiscal Policy})$

Income Tax Rate Change Period=

1

Units: Year [0,70,1]

Income Tax Rate Change Time=

1995

Units: Year [1980,2050,1]

Increase in Reserves=

Open Market Purchase

Units: Billion Yen/Year

Inflation Rate=

$( (\text{Price Level} - \text{"Price Level (-1)"}) / \text{"Price Level (-1)} ) * \text{per Year}$

Units: 1/Year

"Inflation Rate (%)"=

$\text{Inflation Rate} * \text{"Conversion to \%"}$

Units: Percent/Year

Inflation Rate Expectation= INTEG (  
Changes in Adaptive IR,  
Inflation Rate)

Units: 1/Year

Adaptive Expectations based on the average adjustment time  
horizon of inflation rate.

INITIAL Aggregate Demand Forecasting=  
Potential GDP

Units: Billion YenReal/Year

"INITIAL Aggregate Demand Forecasting (Long-run)"=  
Potential GDP

Units: Billion YenReal/Year

"INITIAL Call Rate (nominal)"=  
0.02

Units: 1/Year [0,0.025,0.001]

"INITIAL Capital (PP&E) (Producer)"=  
"Initial Capital (real)" \* Price Level \* Initial Capital Share Ratio

Units: Billion Yen

"Initial Capital (real)"=  
2.7e+06

Units: Billion YenReal [50000,3e+06,10000]

original value = 2700 Japan Macro = 539742

"INITIAL Capital PP&E (real)"=  
"Initial Capital (real)"



Units: Billion YenReal

Initial Capital Share Ratio=

1

Units: Dmnl

INITIAL Capital under Construction=

"Investment (real)"\*Construction Period

Units: Billion YenReal

"INITIAL Cash (Household)"=

"Desired Cash (Household)"

Units: Billion Yen

INITIAL College Students=

2000

Units: thousand people

Original value used in flow approach= 5

"INITIAL Currency Outstanding (Central Bank)"=

"INITIAL Cash (Household)"

+ "INITIAL Vault Cash (Banks)"

Units: Billion Yen

"INITIAL Debt (Banks)"=

0

Units: Billion Yen [0,5000,500]

originally 0

"INITIAL Debt (Government)"=

150000

Units: Billion Yen [0,800000,5000]

62410

"INITIAL Demand Deposit (Producer)"=

Desired Investment / per Year

+ Initial Demand Deposits Change

Units: Billion Yen

Originally. Desired Investment / per Year former stock approach =

27480

"INITIAL Demand Deposits (Banks)"=

"INITIAL Demand Deposit (Producer)"

+ "INITIAL Demand Deposits (Household)"

Units: Billion Yen

"INITIAL Demand Deposits (Household)"=

80000

Units: Billion Yen [30000,100000,10000]

30000 FoF Data in 1980

Initial Demand Deposits Change=

0

Units: Billion Yen [-70000,80000,10000]

"INITIAL Deposits (Government)"=

0

Units: Billion Yen

INITIAL Employed Labor=

55520

Units: thousand people [40000,60000,1000]

Original value used in flow approach = 64

"INITIAL F/F: Capital Shares"=

"INITIAL Shares (Household)"

- "INITIAL Share Capital (Producer)"

Units: Billion Yen

"INITIAL F/F: Demand Deposits"=

"INITIAL Demand Deposit (Producer)"

+ "INITIAL Demand Deposits (Household)"

- "INITIAL Demand Deposits (Banks)"

Units: Billion Yen

"INITIAL F/F: Government Bonds"=

"INITIAL Government Bonds (Household)"

+ "INITIAL Government Bonds (Banks)"

+ "INITIAL Government Bonds (Central Bank)"

- "INITIAL Debt (Government)"

Units: Billion Yen

Initial Gov Bonds Holding Ratio of Banks=

0.8

Units: Dmnl [0,1,0.05]

Initial Gov Bonds Holding Ratio of Central Bank=

0.07

Units: Dmnl [0,1,0.005]

Initial Gov Bonds Holding Ratio of Household=

1

- Initial Gov Bonds Holding Ratio of Banks

- Initial Gov Bonds Holding Ratio of Central Bank

Units: Dmnl

"INITIAL Government Bonds (Banks)"=

"INITIAL Debt (Government)" \* Initial Gov Bonds Holding Ratio of Banks

Units: Billion Yen

"INITIAL Government Bonds (Central Bank)"=

"INITIAL Debt (Government)" \* Initial Gov Bonds Holding Ratio of Central

Bank

Units: Billion Yen

"INITIAL Government Bonds (Household)"=

"INITIAL Debt (Government)" \* Initial Gov Bonds Holding Ratio of Household

Units: Billion Yen

"INITIAL Government Deposits (Central Bank)"=

"INITIAL Deposits (Government)"

Units: Billion Yen

INITIAL High School=

4621

Units: thousand people

The initial value for all Japanese high school students in 1980.

Original value used = 5

INITIAL Inventory=

Price Level \* Desired Inventory

Units: Billion Yen

"INITIAL Inventory (real)"=

Desired Inventory

Units: Billion YenReal

Initial Labor Force= INITIAL(

Labor Force)

Units: thousand people

"INITIAL Loan (Banks)"=

"INITIAL Loans from Banks (Household)"

+ "INITIAL Loans from Banks (Producer)"

Units: Billion Yen

"INITIAL Loan (Central Bank)"=

"INITIAL Debt (Banks)"

Units: Billion Yen

"INITIAL Loans from Banks (Household)"=

0

Units: Billion Yen

"INITIAL Loans from Banks (Producer)"=

300000

Units: Billion Yen [0,500000,10000]

original flow approach = 791 No basis for this initial value.

Arbitrarily chosen.

INITIAL Population 0 to 14=

27520

Units: thousand people

The initial number of ppl aged 0-14 in 1980.

Initial Potential GDP=

300000

Units: Billion YenReal/Year [200000,500000,100000]

original value flow approach = 300

INITIAL Price Level=

1

Units: Yen/YenReal [0.5,1.5,0.1]

0.883268 Optimized value under "ConsumOpt" settings

"INITIAL Reserves (Banks)"=

Required Reserves \* Initial Reserves Coefficient

Units: Billion Yen

Arbitrary chosen

"INITIAL Reserves (Central Bank)"=

"INITIAL Reserves (Banks)"

Units: Billion Yen

Initial Reserves Coefficient=

1

Units: Dmnl [1,1.5,0.05]

This is used to avoid Maximum Loanable Funds=0 at the initial point of simulation in scenario analysis when SWITCH Maximum Loanable Funds is turned on.

"INITIAL Retained Earnings (Bank)"=  
"INITIAL Vault Cash (Banks)"  
+ "INITIAL Reserves (Banks)"  
+ "INITIAL Government Bonds (Banks)"  
+ "INITIAL Loan (Banks)"  
- "INITIAL Debt (Banks)"  
- "INITIAL Demand Deposits (Banks)"  
- "INITIAL Time Deposits (Banks)"

Units: Billion Yen

"INITIAL Retained Earnings (Central Bank)"=  
"INITIAL Loan (Central Bank)"  
+ "INITIAL Government Bonds (Central Bank)"  
- "INITIAL Currency Outstanding (Central Bank)"  
- "INITIAL Reserves (Central Bank)"  
- "INITIAL Government Deposits (Central Bank)"

Units: Billion Yen

"INITIAL Retained Earnings (Government)"=  
"INITIAL Deposits (Government)"  
- "INITIAL Debt (Government)"

Units: Billion Yen

"INITIAL Retained Earnings (Household)"=  
"INITIAL Cash (Household)"  
+ "INITIAL Demand Deposits (Household)"  
+ "INITIAL Government Bonds (Household)"  
+ "INITIAL Shares (Household)"  
+ "INITIAL Time Deposits (Household)"  
- "INITIAL Loans from Banks (Household)"

Units: Billion Yen

"INITIAL Retained Earnings (Producer)"=

INITIAL Inventory

+ "INITIAL Demand Deposit (Producer)"

+ "INITIAL Capital (PP&E) (Producer)"

- "INITIAL Loans from Banks (Producer)"

- "INITIAL Share Capital (Producer)"

Units: Billion Yen

"INITIAL Share Capital (Producer)"=

"INITIAL Capital (PP&E) (Producer)" - "INITIAL Loans from Banks  
(Producer)"

Units: Billion Yen

"INITIAL Shares (Household)"=

"INITIAL Share Capital (Producer)"

Units: Billion Yen

"INITIAL Time Deposits (Banks)"=

"INITIAL Time Deposits (Household)"

Units: Billion Yen

"INITIAL Time Deposits (Household)"=

80000

Units: Billion Yen

No logical basis for choosing the value yet.

INITIAL Unemployed Labor=

1000



Units: thousand people [0,3000,100]

original value used in flow approach model = 2

"INITIAL Vault Cash (Banks)"=

"Desired Vault Cash (Banks)"

Units: Billion Yen

INITIAL Voluntary Unemployed=

10000

Units: thousand people

Original value used = 9.8576

"Interest Income (Banks)"=

"Interest paid by Producer (Banks)"

+ "Interest paid by Household (Banks)"

+ "Interest paid by the Government (Banks)"

Units: Billion Yen/Year

"Interest Income (Household)"=

"Interest Income from Demand Deposits (Household)"

+ "Interest Income from Time Deposits (Household)"

+ "Interest Income from Government Bonds (Household)"

Units: Billion Yen/Year

"Interest Paid by Banks (Central Bank)"=

"Debt (Banks)" \* Discount Lending Rate

Units: Billion Yen/Year

Interest Paid by the Government=

"Government Bonds (Central Bank)" \* Interest Rate on Government Bonds

Units: Billion Yen/Year

"Interest Payment (Government)"=

"Debt (Government)" \* Interest Rate on Government Bonds

Units: Billion Yen/Year

INITIAL Population 15 to 44=

INITIAL Population 15 to 64 \* Portion to 15 to 44

Units: thousand people

INITIAL Population 15 to 64=

78880

Units: thousand people

78.835

INITIAL Population 45 to 64=

INITIAL Population 15 to 64 \*(1 - Portion to 15 to 44)

Units: thousand people

INITIAL Population plus 65=

10650

Units: thousand people

Original value used = 10.647

Initial Required Reserve Ratio=

0.02

Units: Dmnl [0.001,0.1,0.001]

INITIAL Wage Rate=

2.1

Units: Yen/(Year\*Person) [1,3,0.1]

Original value in flow approach = 2

"Interest Income from Government Bonds (Household)"=

"Government Bonds (Household)" \* Interest Rate on Government Bonds

Units: Billion Yen/Year

"Interest paid by Producer (Banks)"=

"Loans from Banks (Producer)" \* Prime Rate

Units: Billion Yen/Year

"Interest paid by the Government (Banks)"=

"Government Bonds (Banks)" \* Interest Rate on Government Bonds

Units: Billion Yen/Year

"Interest Payments (Banks)"=

"Interest Paid by Banks (Central Bank)"

+ "Interest Paid by Banks (Household)"

Units: Billion Yen/Year

Interest Rate on Demand Deposits=

"Call Rate (nominal)" + Margins on Demand Deposits

Units: 1/Year

"Interest Rate on Demand Deposits (%)"=

Interest Rate on Demand Deposits \* "Conversion to %"

Units: Percent/Year

Interest Rate on Government Bonds=

"Call Rate (nominal)" + Margin on Government Bonds

Units: 1/Year

"Interest Rate on Government Bonds (%)"=

Interest Rate on Government Bonds \* "Conversion to %"

Units: Percent/Year

Interest Rate on Newly Issued Gov Bond 10y

Units: Percent/Year

Interest Rate on Savings Deposits=

"Call Rate (nominal)" + Margins on Savings Deposits

Units: 1/Year

"Interest Rate on Savings Deposits (%)"=

Interest Rate on Savings Deposits \* "Conversion to %"

Units: Percent/Year

Interest Sensitivity=

"Interest Sensitivity (base)"

+ Change in Interest Sensitivity \* PULSE(Interest Sensitivity Change Time,

Interest Sensitivity Change Period)

Units: Dmnl [0,1,0.001]

Less value, more sensitive it becomes.

"Interest Sensitivity (base)"=

0.4

Units: Dmnl [0.3,1,0.01]

Interest Sensitivity Change Period=

1

Units: Year [0,20,1]

Interest Sensitivity Change Time=

2000

Units: Year [1980,2040,1]

"Inventory (real) (-1)"=

DELAY FIXED("Inventory (real)", 1, "Inventory (real)")

Units: Billion YenReal

"Inventory (real) Growth Rate"=

XIDZ("Inventory (real)" - "Inventory (real) (-1)", "Inventory (real) (-1)", 0) \* Growth Unit

Units: 1/Year

"Inventory (real)"= INTEG (

"GDP (real)" - "Sales (real)",  
"INITIAL Inventory (real)")

Units: Billion YenReal

Inventory Investment=

"GDP (real)" - "Sales (real)"

Units: Billion YenReal/Year

"Investment (nominal) (-1)"=

DELAY FIXED("Capital Investment (Producer)", 1, "Capital Investment (Producer)")

Units: Billion Yen/Year

"Investment (nominal) Growth Rate (%)"=

"Investment (nominal) Growth Rate" \* "Conversion to %"

Units: Percent/Year

"Investment (nominal) Growth Rate"=

ZIDZ( "Capital Investment (Producer)"-"Investment (nominal) (-1)" ,

"Investment (nominal) (-1)"

)

\* Growth Unit

Units: 1/Year

"Investment (real) (-1)"=

DELAY FIXED("Investment (real)", 1, "Investment (real)")

Units: Billion YenReal/Year

"Investment (real) Growth Rate (%)"=

"Investment (real) Growth Rate" \* "Conversion to %"

Units: Percent/Year

"Investment (real) Growth Rate"=

ZIDZ( "Investment (real)"-"Investment (real) (-1)" , "Investment (real) (-1)"

)

\* Growth Unit

Units: 1/Year

"Investment (real)"=

ZIDZ("Capital Investment (Producer)", Price Level)

Units: Billion YenReal/Year

"Investment in Government Security (Banks)"=

Government Securities Newly Issued \* "Gov Bond Holding Ratio (Banks)"

Units: Billion Yen/Year

"Investment in Government Security (Household)"=

Government Securities Newly Issued \* "Gov Bonds Holding Ratio in Issuance (Household)"

Units: Billion Yen/Year

Labor Force=

Employed Labor + Unemployed Labor

Units: thousand people

Labor Market Flexibility=

1

Units: Dmnl [0.1,6,0.1]

Labor Ratio=

Labor Force/Desired Labor

Units: Dmnl

"Labor Ratio Elasticity (Effect on Wage)"=

1

Units: Dmnl [0,2,0.1]

Formerly, 0.15

Lending Disapproval Ratio=

0

Units: Dmnl [0,1,0.005]

"Liquidity Deficit (Cash Flow Deficit)"=

Cash Flow from Operating Activities

+ Cash Flow from Investing Activities

- "Debt Finance Expenditures (Producer)"

- "Equity Finance Expenditures (Producer)"

Units: Billion Yen/Year

"Loan (Banks) (-1)"=

DELAY FIXED("Loans Receivable (Banks)", 1, "Loans Receivable (Banks)")

Units: Billion Yen

"Loan (Banks) (1981-2013)"

Units: Billion Yen

"Loan (Banks) Growth Rate (%)"=

"Loan (Banks) Growth Rate" \* "Conversion to %"

Units: Percent/Year

"Loan (Banks) Growth Rate"=

ZIDZ("Loans Receivable (Banks)" - "Loan (Banks) (-1)",

"Loan (Banks) (-1)"

)

\* Growth Unit

Units: 1/Year

"Loans from Banks (Producer) (1981-2013)":INTERPOLATE:

Units: Billion Yen

"Loans from Banks (Producer)"= INTEG (

"Borrowings (Producer)"-"Debt Redemption (Producer)",



"INITIAL Loans from Banks (Producer)")

Units: Billion Yen

"Loans Receivable (Banks)"= INTEG (

"Corporate lending (Banks)"+"Household Lending (Banks)"-"Debt  
Redemption (Producer)" , "INITIAL Loan (Banks)")

Units: Billion Yen

"Lump-sum Taxes"=

0

+ STEP ( "Change in Lump-sum Taxes" , Starting Time for Fiscal Policy )

Units: Billion Yen/Year

"M0 (1980-2017)"

Units: Billion Yen

Data Source: Bank of Japan M0

"M1 (1980-2017)"

Units: Billion Yen

Data Source: Bank of Japan M1

"M1 (Data) (-1)"=

DELAY FIXED("Money Stock (M1 Data)" , 1 , "Money Stock (M1 Data)")

Units: Billion Yen

"M1 (Data) Growth Rate (%)"=

"M1 (Data) Growth Rate" \* "Conversion to %"

Units: Percent/Year

"M3 Japan (1981-2017)"

Units: Billion Yen

Data Source: Bank of Japan M3 (statistical change after 2003) Definition corresponds to that of M2 in the model.

"M1 (Data) Growth Rate"=

$$\frac{\text{ZIDZ}(\text{"Money Stock (M1 Data)" - "M1 (Data) (-1)"}, \text{"M1 (Data) (-1)"})}{\text{Growth Unit}}$$

Units: 1/Year

"M2 (Data) (-1)"=

$$\text{DELAY FIXED}(\text{"Money Stock (M2 Data)"}, 1, \text{"Money Stock (M2 Data)"})$$

Units: Billion Yen

"M2 (Data) Growth Rate (%)"=

$$\text{"M2 (Data) Growth Rate"} * \text{"Conversion to \%"}$$

Units: Percent/Year

"M2 (Data) Growth Rate"=

$$\frac{\text{ZIDZ}(\text{"Money Stock (M2 Data)" - "M2 (Data) (-1)"}, \text{"M2 (Data) (-1)"})}{\text{Growth Unit}}$$

Units: 1/Year

Margins on Demand Deposits=

$$-0.01$$

Units: 1/Year [-0.01,0.01,0.001]

Margins on Demand Deposits < Margins on Time Deposits

maturation 14 to 15=

(Population 0 to 14)

$$\begin{aligned} & * ( 1 \\ & \quad - \text{mortality 0 to 14} ) \\ & / 15 \end{aligned}$$

Units: thousand people/Year

maturation 44 to 45=

(( Population 15 to 44 ))

$$\begin{aligned} & * ( 1 \\ & \quad - \text{mortality 15 to 44} ) \\ & / 30 \end{aligned}$$

Units: thousand people/Year

Maximum Loanble Funds=

Maximum Loanable Amount\*per Year

Units: Billion Yen/Year

"Money Multiplier (Demand Deposits)"=

$$\begin{aligned} & \text{ZIDZ( "Actual Currency Ratio (M1)" + 1,} \\ & \quad \text{"Actual Currency Ratio (M1)" + "Actual Reserve Ratio (M1)" } \\ & \quad \text{)} \end{aligned}$$

Units: Dmnl

"Money Multiplier (Demand&Time Deposits)"=

$$\begin{aligned} & \text{ZIDZ("Actual Currency Ratio (M2)" + 1,} \\ & \quad \text{"Actual Currency Ratio (M2)" + "Actual Reserve Ratio (M2)" } \\ & \quad \text{)} \end{aligned}$$

Units: Dmnl

"Money Multiplier (M1 Data)"=

ZIDZ("Money Stock (M1 Data)", Base Money )

Units: Dmnl

"Money Multiplier (M2 Data)"=

ZIDZ("Money Stock (M2 Data)", Base Money )

Units: Dmnl

"Money Stock (M1 Data)"=

"Currency Outstanding (Central Bank)"  
+ "Demand Deposits (Banks)"

Units: Billion Yen

"Money Stock (M1) Estimation (Base)"=

Base Money \* "Money Multiplier (Demand Deposits)"

Units: Billion Yen

"Money Stock (M1) Estimation (Data)"=

"High-Powered Money" \* "Money Multiplier (Demand Deposits)"

Units: Billion Yen

"Money Stock (M2) Estimation (Base)"=

Base Money \* "Money Multiplier (Demand&Time Deposits)"

Units: Billion Yen

"Money Stock (M2) Estimation (Data)"=

"High-Powered Money" \* "Money Multiplier (Demand&Time Deposits)"

Units: Billion Yen

new employment=

MAX( 0,  
IF THEN ELSE( total graduation \* (1 - unemployment rate )  
>=Voluntary Unemployed \* per Year ,  
Voluntary Unemployed \* per Year ,  
total graduation \* (1 - unemployment rate) )  
)

Units: thousand people/Year

new unemployment=

total graduation \* unemployment rate

Units: thousand people/Year

New graduates are employed according to the current job market condition assumed to be represented by the unemployment rate.

"Open Market Purchase (Banks Sale)"=

IF THEN ELSE (  
"Government Bonds (Banks)" > 0,  
("Open Market Purchase Operation (permanent)" +  
PULSE(Open Market Purchase Time, Purchase Period)  
\* "Open Market Purchase Operation (temporary)" )  
\* "Government Bonds (Banks)"  
+  
PULSE(Open Market Purchase Time 2, Purchase Period 2)  
\* "Open Market Purchase Operation 2 (temporary)"  
\* "Government Bonds (Banks)"  
+ Purchase Amount\*PULSE(Purchase Change Time, Purchase  
Change Period  
) ,  
0 )

Units: Billion Yen/Year

"Open Market Purchase Operation (permanent)"=  
0.014

Units: 1/Year [0.015,0.1,0.001]

"Open Market Purchase Operation (temporary)"=  
0

Units: 1/Year [0,0.3,0.01]

"Open Market Purchase Operation 2 (temporary)"=  
0

Units: 1/Year [0,0.3,0.01]

Open Market Purchase Time=  
1988

Units: Year [1980,2020,1]

Open Market Purchase Time 2=  
2005

Units: Year [1980,2050,1]

Open Market Sale=

"Open Market Sale (Banks Purchase)"

Units: Billion Yen/Year

"Open Market Sale (Banks Purchase)"=

IF THEN ELSE( "Government Bonds (Central Bank)"<=0, 0,

"Open Market Sale Operation (permanent)"

+ PULSE(Open Market Sale Time, Sales Period)

\* "Open Market Sale Operation (temporary)"  
 \* "Government Bonds (Central Bank)"  
 + PULSE(Open Market Sale Time 2, Sales Period 2)  
 \* "Open Market Sale Operation 2 (temporary)"  
 \* "Government Bonds (Central Bank)"  
 + Sales Amount\*PULSE(Sales Change Time, Sales  
 Change Period)  
 )

Units: Billion Yen/Year

"Open Market Sale Operation (permanent)"=  
 0

Units: 1/Year [0,0.1,0.005]

"Open Market Sale Operation (temporary)"=  
 0

Units: 1/Year [0,0.5,0.005]

"Open Market Sale Operation 2 (temporary)"=  
 0

Units: 1/Year [0,0.3,0.01]

Open Market Sale Time=  
 1990

Units: Year [1980,2020,1]

Open Market Sale Time 2=  
 2005

Units: Year [1990,2050,1]

per Year=

1

Units: 1/Year

"Population 0 to 14 (1980-2013)"

Units: thousand people

Population 15 to 44= INTEG (

maturation 14 to 15-deaths 15 to 44-maturation 44 to 45,

INITIAL Population 15 to 44)

Units: thousand people

"Population 15 to 64 (1980-2013)"

Units: thousand people

Potential GDP=

EXP(Technological Change \* (Time-INITIAL TIME)) \* Initial Potential  
GDP \* POWER ( "Capital PP&E (real)" / "Initial Capital (real)" ,  
Exponent on Capital ) \* POWER (Labor Force / Initial Labor Force ,  
Exponent on Labor  
)

Units: Billion YenReal/Year

Potential GDP Growth Rate=

ZIDZ(Potential GDP - "Potential GDP (-1)",  
"Potential GDP (-1)"  
)  
\* Growth Unit

Units: 1/Year



"Potential GDP Growth Rate (%)"=

Potential GDP Growth Rate \* "Conversion to %"

Units: Percent/Year

Price Level= INTEG (

Change in Price,

INITIAL Price Level)

Units: Yen/YenReal

Primary Balance Change Period=

0

Units: Year [0,70,1]

Prime Rate=

"Call Rate (nominal)" + Prime Rate Premium

Units: 1/Year

"Prime Rate (real) Smooth 3"=

SMOOTH3( "Prime Rate (real)", Delay Time for Prime Rate Smoothing)

Units: 1/Year

Supplementary variable created for an experiment to check to

compare with Adaptive Expectations of Prime Rate.

"Prime Rate (real)"=

Prime Rate - Inflation Rate Expectation

Units: 1/Year

"Prime Rate Long-term (1980-2016)":INTERPOLATE:

Units: Percent/Year

Data Source: Bank of Japan statistics,

"Prime Rate Short-term (1980-2016)":INTERPOLATE:

Units: Percent/Year

Data Source: Bank of Japan website.

"Interest Income from Demand Deposits (Household)"=

"Demand Deposits (Household)" \* Interest Rate on Demand Deposits

Units: Billion Yen/Year

"Interest Income from Time Deposits (Household)"=

"Savings Deposits (Household)" \* Interest Rate on Savings Deposits

Units: Billion Yen/Year

"Interest Paid by Banks (Household)"=

"Interest Income from Demand Deposits (Household)"

+ "Interest Income from Time Deposits (Household)"

Units: Billion Yen/Year

"Interest paid by Household (Banks)"=

0

Units: Billion Yen/Year

"Inventory (Producer)"= INTEG (

"GDP (Revenues)"-Sales,

INITIAL Inventory)

Units: Billion Yen

Total monetary value of Raw-materials, work-in-process products and finished goods that are considered to be the portion of a business's assets that are ready or will be ready for sale. Any market goods which are produced are purchased by someone. In the case where a good is produced and unsold, they are recorded as

inventories in the standard accounting convention. This applies in the macro-level.

Inventory Ratio=

$$\text{"Inventory (real)" / Desired Inventory}$$

Units: Dmnl

"Investment in Shares (Household)"=

$$\text{Capital Shares Newly Issued}$$

Units: Billion Yen/Year

labor force participation ratio=

$$\text{Labor Force / (Voluntary Unemployed + Labor Force)}$$

Units: Dmnl

Lending by Central Bank=

$$0$$

Units: Billion Yen/Year

Lending Period=

$$1$$

Units: Year [1,20,1]

Lending Time=

$$1996$$

Units: Year [1980,2015,1]

"Loan (Central Bank)"= INTEG (

$$\text{"Discount Window Lending (Central Bank)" - "Debt Redemption (Banks)",$$
$$\text{"INITIAL Loan (Central Bank)"})$$

Units: Billion Yen

"Loans from Banks (Household)"= INTEG (  
"Borrowings (Household)"-"Debt Redemption (Household)",  
"INITIAL Loans from Banks (Household)")

Units: Billion Yen

"Long-run Production Gap"=  
"Aggregate Demand Forecasting (Long-run)"  
/ Full Capacity GDP

Units: Dmnl

Margin on Government Bonds=

0.015

Units: 1/Year [0.005,0.1,0.001]

Marginal Propensity to Consume=

0.64

Units: Dmnl [0.5,1,0.005]

Original flow approach = 0.64 Optimized value under "ConsumOpt"  
settings = 0.552321

Margins on Savings Deposits=

0.01

Units: 1/Year [0.01,0.15,0.001]

Margins on Demand Deposits < Margins on Time Deposits

maturation 64 to 65=

(( Population 45 to 64 ) )

\* ( 1

- mortality 45 to 64)

/20

Units: thousand people/Year

Maximum Loanable Amount=

$$\text{MAX}(\text{"Reserves (Banks)" / Required Reserve Ratio} \\ - (\text{"Demand Deposits (Banks)" + "Time Deposits (Banks)"}, \\ 0 \\ )$$

Units: Billion Yen

"Money Stock (M2 Data)"=

$$\text{"Currency Outstanding (Central Bank)"}$$
$$+ \text{Total Deposits Outstanding}$$

Units: Billion Yen

mortality 0 to 14=

$$0.00197894$$

Units: 1/Year

mortality 15 to 44=

$$0.00128309$$

Units: 1/Year

Optimized value from population experiment model.

mortality 45 to 64=

$$1.92037e-05$$

Units: 1/Year

Optimized value from Population experiment model

mortality plus 65=

0.0326484

Units: 1/Year

"Net Cash-flow"=

Cash inflow - Cash outflow

Units: Billion Yen/Year

Net employment=

IF THEN ELSE( Desired Labor - Employed Labor < Unemployed Labor ,

( Desired Labor - Employed Labor ) /Time to adjust labor

force

,

Unemployed Labor/Time to adjust labor force

)

Units: thousand people/Year

Labor market has the invisible adjusting mechanism depending on

the desired labor, which itself is dependent on various factors.

"Net Investment (real)"=

( "Desired Capital-Output Ratio"

- "Capital-Output Ratio" )

\* "Aggregate Demand Forecasting (Long-run)"

Units: Billion YenReal

Newly Issued Capital Shares=

Desired Financing \* Direct Financing Ratio

Units: Billion Yen/Year

Nominal GDP by components=

"Consumption (1980-2013)"

+ "Capital Investment (Producer) (1980-2013)"

+ "Government Expenditures (1980-2013)"

Units: Billion Yen/Year

Normal Inventory Coverage=

0.1

Units: Year [0.1,1,0.01]

Open Market Purchase=

"Open Market Purchase (Banks Sale)"

Units: Billion Yen/Year

"Output Ratio Elasticity (Effect on Price)"=

1

Units: Dmnl [0,2,0.1]

"Payments (Producer)"=

"Wages (Producer)"

+ "Tax Payments (Producer)"

Units: Billion Yen/Year

Population 0 to 14= INTEG (

births-deaths 0 to 14-maturation 14 to 15,

INITIAL Population 0 to 14)

Units: thousand people

Population 15 to 64=

Population 15 to 44 +Population 45 to 64

Units: thousand people

Population 45 to 64= INTEG (  
maturation 44 to 45-deaths 45 to 64-maturation 64 to 65,  
INITIAL Population 45 to 64)

Units: thousand people

Population plus 65= INTEG (  
maturation 64 to 65-deaths plus 65,  
INITIAL Population plus 65)

Units: thousand people

Portion to 15 to 44=  
0.884684

Units: Dmnl

"Potential GDP (-1)"=  
DELAY FIXED(Potential GDP, 1, Potential GDP)

Units: Billion YenReal/Year

Price Elasticity of Consumption=  
3

Units: Dmnl [0.8,4,0.05]

"Price Level (-1)"= DELAY FIXED (  
Price Level, 1, Price Level)

Units: Yen/YenReal

"Price Level (1980-2013)"

Units: Yen/YenReal

Need to find the calculation method of original data



Primary Balance=

Tax Revenues-Government Expenditures

Units: Billion Yen/Year

Primary Balance Change=

0

Units: Dmnl [-0.05,0.05,0.01]

Primary Balance Change Time=

1995

Units: Year [1980,2040,1]

Primary Balance Ratio=

1 + Primary Balance Change\*PULSE( Primary Balance Change Time, Primary  
Balance Change Period  
)

Units: Dmnl

Previously, 1 + STEP(Primary Balance Change, Primary Balance  
Change Time)

Primary Balance to GDP Ratio=

ZIDZ(Primary Balance, "GDP (Revenues)")

Units: Dmnl

"Primary Balance to GDP Ratio (%)"=

Primary Balance to GDP Ratio \* "Conversion to %"

Units: Percent

"Prime Rate (%)"=

Prime Rate \* "Conversion to %"

Units: Percent/Year

Prime Rate Premium=

0.008

Units: 1/Year [0,0.05,0.001]

"Private&Public Capital Investment (1980-2013)"

Units: Billion Yen/Year

Production Ratio=

Potential GDP / "Desired Output (real)"

Units: Dmnl

Productive Population=

High School Students

+ College Students

+ Voluntary Unemployed

+ Employed Labor

+ Unemployed Labor

Units: thousand people

Productive population=

High School Students

+ College Students

+ Voluntary Unemployed

+ Labor Force

Units: Person

Profits=

Profits before Tax - Corporate Tax

Units: Billion Yen/Year

Profits before Tax=

"GDP (Revenues)"  
- "Wages (Producer)"  
- "Depreciation (Capital)"  
- "Interest paid by Producer (Banks)"  
- Tax on Poduction

Units: Billion Yen/Year

Purchase Amount=

0

Units: Billion Yen/Year [-2000,5000,500]

Purchase Change Period=

5

Units: Year [0,40,1]

Purchase Change Time=

1980

Units: Year [1980,2050,1]

Purchase Period=

2

Units: Year [1,20,1]

Purchase Period 2=

2

Units: Year [0,20,1]

"Redemption of Gov Bonds (Banks)"=

"Debt Redemption (Government)" \* "Gov Bonds Holding Ratio in Redemption (Banks)"

Units: Billion Yen/Year

"Redemption of Gov Bonds (Central Bank)"=

"Debt Redemption (Government)" \* "Gov Bonds Holding Ratio in Redemption (Central Bank)"

Units: Billion Yen/Year

"Redemption of Gov Bonds (Household)"=

"Debt Redemption (Government)" \* "Gov Bonds Holding Ratio in Redemption (Household)"

Units: Billion Yen/Year

reproductive lifetime=

41.675

Units: Year

Required Reserve Ratio=

Initial Required Reserve Ratio

+ RR Ratio Change \* PULSE(RR Ratio Change Time, RR Change Period)

Units: Dmnl

Required Reserves=

("Demand Deposits (Banks)" + "Time Deposits (Banks)" )

\* Required Reserve Ratio

Units: Billion Yen

Reserve Deficit=

("Reserves (Banks)" - Required Reserves)

Units: Billion Yen

If above zero, reserve surplus.

"Reserves (1980-2013)"

Units: Billion Yen

"Reserves (Banks)"= INTEG (

"Borrowing (Banks)"+"Open Market Purchase (Banks Sale)"+"Redemption of  
Gov Bonds (Banks)"

+Reserves inflow-"Debt Redemption (Banks)"-"Investment in Government Security  
(Banks)"

-"Open Market Sale (Banks Purchase)"-Reserves outflow-Adjusting Vault Cash,

"INITIAL Reserves (Banks)")

Units: Billion Yen

"Reserves (Central Bank)"= INTEG (

"Discount Window Lending (Central Bank)"+"Increase in Reserves"+"Reserves  
Transfer (Gov-CB)"

+"Wages (Central Bank)"-Adjusting Vault Cash-"Debt Redemption (Banks)"-Decrease in  
Reserves

-"Interest Paid by Banks (Central Bank)"-"Reserves Transfer (CB-Gov)",

"INITIAL Reserves (Central Bank)")

Units: Billion Yen

Reserves Adjustment Time=

1

Units: Year [1,3,0.1]

Reserves Flow Deficit=

Reserves inflow

- + "Redemption of Gov Bonds (Banks)"
- Reserves outflow
- "Debt Redemption (Banks)"
- "Investment in Government Security (Banks)"
- Adjusting Vault Cash

Units: Billion Yen/Year

Reserves inflow=

Reserves Inflow from Government

- + "Reserves Inflow from Intra-sectoral Transactions"
- + Reserves Inflow from Central Bank

Units: Billion Yen/Year

Reserves Inflow from Central Bank=

"Wages (Central Bank)"

Units: Billion Yen/Year

Reserves Inflow from Government=

Government Expenditures

- + "Interest paid by the Government (Banks)"
- + "Redemption of Gov Bonds (Household)"

Units: Billion Yen/Year

"Reserves Inflow from Intra-sectoral Transactions"=

"Interest Income (Household)"

- + "Interest paid by Household (Banks)"
- + "Interest paid by Producer (Banks)"
- + "Wages (Banks)"

Units: Billion Yen/Year

Reserves outflow=

"Wages (Banks)"  
+ "Interest Payments (Banks)"  
+ "Investment in Government Security (Household)"  
+ Tax Revenues from Households  
+ Tax Revenues from Producer  
+ "Interest paid by Producer (Banks)"  
+ "Interest paid by Household (Banks)"  
+ "Tax Payments (Banks)"

Units: Billion Yen/Year

"Reserves Transfer (CB-Gov)"=

Government Securities Newly Issued  
+ Tax Revenues

Units: Billion Yen/Year

"Reserves Transfer (Gov-CB)"=

Government Expenditures  
+ "Interest Income from Government Bonds (Household)"  
+ "Interest paid by the Government (Banks)"  
+ "Redemption of Gov Bonds (Banks)"  
+ "Redemption of Gov Bonds (Household)"

Units: Billion Yen/Year

"Retained Earnings (Bank)"= INTEG (

"Interest Income (Banks)"-"Interest Payments (Banks)"-"Tax Payments (Banks)"  
-"Wages (Banks)",

"INITIAL Retained Earnings (Bank)")

Units: Billion Yen

"Retained Earnings (Central Bank)"= INTEG (
  
     "Interest Paid by Banks (Central Bank)"+"Interest Paid by the
  
 Government-Transfers to the Treasury
  
 -"Wages (Central Bank)",
  
     "INITIAL Retained Earnings (Central Bank)")

Units: Billion Yen

"Retained Earnings (Government)"= INTEG (
  
     Tax Revenues+Transfers from Central Bank-Government Expenditures-"Interest
  
 Payment (Government)"
  
 ,
  
     "INITIAL Retained Earnings (Government)")

Units: Billion Yen

"Retained Earnings (Household)"= INTEG (
  
     "Income (Household)"-Consumption-"Interest paid by Household (Banks)"-"Tax
  
 Payments (Household)"
  
 ,
  
     "INITIAL Retained Earnings (Household)")

Units: Billion Yen

"Retained Earnings (Producer)"= INTEG (
  
     "GDP (Revenues)"-Corporate Tax -"Depreciation (Capital)"-Dividends
  
     -"Interest paid by Producer (Banks)" - Tax on Production
  
     -"Wages (Producer)" ,
  
     "INITIAL Retained Earnings (Producer)"

)

Units: Billion Yen



"retiring (employed)"=

(1-SWITCH Labor Force Participation)\*maturation 64 to 65 \* Employed Labor Ratio

+

SWITCH Labor Force Participation \* labor force participation ratio \* maturation 64 to 65

Units: thousand people/Year

"retiring (unemployed)"=

maturation 64 to 65 \* (1-Employed Labor Ratio)\*SWITCH Retiring

Units: thousand people/Year

"retiring (voluntary)"=

maturation 64 to 65 \* (1 - labor force participation ratio)\*SWITCH Labor Force Participation

Units: thousand people/Year

"Revenue-dependent Expenditure"=

Tax Revenues \* Primary Balance Ratio

Units: Billion Yen/Year

RR Change Period=

1

Units: Year [0,50,1]

RR Ratio Change=

0

Units: Dmnl [-0.019,0.5,0.001]

RR Ratio Change Time=

2000

Units: Year [1980,2050,1]

Sales=

"Sales (real)" \* Price Level

Units: Billion Yen/Year

"Sales (real)"=

MIN("Aggregate Demand (real)", "GDP (real)" + "Inventory (real)"\*per Year )

Units: Billion YenReal/Year

Economy can only demand the amount no greater than the sum of what's left (inventory) and what has just produced (GDP real) even when Aggregate Demand becomes higher.

Sales Amount=

1000

Units: Billion Yen/Year [0,5000,500]

Sales Change Period=

3

Units: Year [0,20,1]

Sales Change Time=

1986

Units: Year [1980,2050,1]

Sales Period=

1

Units: Year [1,70,1]

Sales Period 2=

1

Units: Year [0,20,1]

"Saving (Household)"=

(Disposable Income - Consumption)\*Savings Ratio

Units: Billion Yen/Year

"Savings Deposits (Household)"= INTEG (

"Saving (Household)",

"INITIAL Time Deposits (Household)")

Units: Billion Yen

Savings Ratio=

0.56

Units: Dmnl [0,0.7,0.02]

previously 0.4

"Share Capital (Producer)"= INTEG (

Capital Shares Newly Issued,

"INITIAL Share Capital (Producer)")

Units: Billion Yen

Starting Time for Fiscal Policy=

1995

Units: Year [1980,2040,1]

SWITCH Call Rate=

0

Units: Dmnl [0,1,1]

SWITCH Cash=

1

Units: Dmnl [0,1,1]

0=off (Desired Cash) , 1=on (Currency Ratio)

SWITCH Currency Ratio Random Walk=

1

Units: Dmnl [0,1,1]

0=off, 1= Random walk

SWITCH Desired Cash=

0

Units: Dmnl [0,1,1]

SWITCH Desired Financing=

0

Units: Dmnl [0,1,1]

SWITCH fertility=

0

Units: Dmnl [0,1,1]

SWITCH GDP Gap Reverse=

0

Units: Dmnl [0,1,1]

0=off, 1=on

SWITCH Gov Expenditure=

1

Units: Dmnl [0,1,1]

SWITCH Labor Force Participation=

1

Units: Dmnl [0,1,1]

SWITCH Max Lovable Funds=

1

Units: Dmnl [0,1,1]

0=Off, 1=ON

SWITCH Prime Rate=

0

Units: Dmnl [0,1,1]

SWITCH Reserve Constraint=

0

Units: Dmnl [0,1,1]

This switch should always be turned off unless one needs to

check reserves constraints on banks loans only. Since the model is built with stock approach, no corresponding accounting entries are kept under double entry rule. Thus simulation runs are wrong even though the model can be run.

"SWITCH Reserve Supply (Lending Facility)"=

0

Units: Dmnl [0,1,1]

SWITCH Retiring=

0

Units: Dmnl [0,1,1]

0=off, 1=on

Tax on Production=

"GDP (Revenues)" \* Excise Tax Rate

Units: Billion Yen/Year

"Tax Payments (Banks)"=

0

Units: Billion Yen/Year [0,5000,100]

"Tax Payments (Household)"=

Income Tax + "Lump-sum Taxes"

Units: Billion Yen/Year

"Tax Payments (Producer)"=

Tax on Production

+ Corporate Tax

Units: Billion Yen/Year

Tax Revenues=

Tax Revenues from Producer

+ Tax Revenues from Households

+ Tax Revenues from Banks

Units: Billion Yen/Year

"Tax Revenues (1994-2013)"

Units: Billion Yen/Year

Tax Revenues from Banks=

"Tax Payments (Banks)"

Units: Billion Yen/Year

Tax Revenues from Households=

"Tax Payments (Household)"

Units: Billion Yen/Year

Tax Revenues from Producer=

"Tax Payments (Producer)"

Units: Billion Yen/Year

Technological Change=

0.003

Units: 1/Year [0,0.1,0.0005]

original value in flow approach model = 0.003

"Time Deposits (Banks) (1980-2013)"

Units: Billion Yen

"Time Deposits (Banks)"= INTEG (

"Saving (Household)",

"INITIAL Time Deposits (Banks)")

Units: Billion Yen

"Time Deposits (Household) (1981-2013)"

Units: Billion Yen

Time to Adjust Capital=

11

Units: Year [0,30,0.5]

Time to Adjust Forecasting=

0.5

Units: Year [0.4,2,0.1]

"Time to Adjust Forecasting (Long-run)"=

8

Units: Year [0,40,0.05]

Time to Adjust Inventory=

0.7

Units: Year [0.5,8,0.05]

Time to adjust labor force=

1.2

Units: Year

Time to Withdraw Cash=

1

Units: Year [1,5,1]

Total Deposits Outstanding=

"Demand Deposits (Banks)"

+ "Time Deposits (Banks)"

Units: Billion Yen

total fertility=

total fertility table ( Time/Unit Year)

Units: Dmnl

total fertility table(

[(1980,1)-(2030,3)],(1980,2.2),(1983,2.14),(1988,1.79),(1993,1.8),(1998,1



.66),(2003,1.46),(2005,1.4),(2008,1.38),(2010,1.3),(2013,1.29),(2014,1.29),  
(2020,1.4),(2030,1.5))

Units: Dmnl

"Total Gov Debt (1980-2016)"=

"Government Bonds Outstanding (1980-2016)" + "Government Short  
- Term Securities (1980-2016)"

Units: Billion Yen

total graduation=

"HS graduation (not going to college)" + College graduation

Units: thousand people/Year

Total population=

Population 0 to 14  
+ Population 15 to 44  
+ Population 45 to 64  
+ Population plus 65

Units: thousand people

"Transfer Ratio (Central Bank)"=

0.8

Units: Dmnl [0,1,0.005]

Transfers from Central Bank=

Transfers to the Treasury

Units: Billion Yen/Year

Transfers to the Treasury=

IF THEN ELSE("Retained Earnings (Central Bank)">0,

("Retained Earnings (Central Bank)"\*"Transfer  
Ratio (Central Bank)") \* per Year , 0  
)

Units: Billion Yen/Year

"Uncollateralized Call Rate (overnight) (1986-2017)"

Units: Percent/day

Data Source: Bank of Japan statistics

Unemployed Labor= INTEG (  
new unemployment-Net employment-"retiring (unemployed)",  
INITIAL Unemployed Labor)

Units: thousand people

unemployment rate=

Unemployed Labor / Labor Force

Units: Dmnl

"unemployment rate (%)"=

unemployment rate \* "Conversion to %"

Units: Percent

Unit Year=

1

Units: Year

"Vault Cash (1980-2014)"

Units: Billion Yen

"Vault Cash (Banks)"= INTEG (

Cash inflow+Adjusting Vault Cash-Cash outflow,  
"INITIAL Vault Cash (Banks)"

Units: Billion Yen

Velocity of M1=

ZIDZ("GDP (Revenues)", "Money Stock (M1 Data)")

Units: 1/Year

Velocity of M2=

ZIDZ("GDP (Revenues)", "Money Stock (M2 Data)")

Units: 1/Year

Voluntary Unemployed= INTEG (

College graduation+"HS graduation (not going to college)"-deaths 45 to 64-  
new employment-new unemployment-"retiring (voluntary)",

INITIAL Voluntary Unemployed)

Units: thousand people

"Wage (1980-2013)"

Units: Billion Yen/Year

Wage Income=

"Wages (Producer)"

+ "Wages (Banks)"

+ "Wages (Central Bank)"

Units: Billion Yen/Year

Wage Rate= INTEG (

Change in Wage Rate,

INITIAL Wage Rate)

Units: Yen/Year/Person

"Wage Rate (-1)"=

DELAY FIXED(Wage Rate, 1, Wage Rate)

Units: Yen/(Year\*Person)

"Wage Rate (real)"=

ZIDZ(Wage Rate, Price Level)

Units: YenReal/Year/Person

Wage Rate Change=

(Wage Rate - "Wage Rate (-1)") / "Wage Rate (-1)"\*per Year

Units: 1/Year

"Wages (Banks)"=

"Employed Labor (Banks)" \* Wage Rate

Units: Billion Yen/Year

"Wages (Central Bank)"=

"Employed Labor (Central Bank)" \* Wage Rate

Units: Billion Yen/Year

"Wages (Producer)"=

"Employed Labor (Producer)" \* Wage Rate

Units: Billion Yen/Year

Weight of Inventory Ratio=

0.5

Units: Dmnl [0,1,0.1]

Originally, 0

Window Guidance=

1

Units: Dmnl [0,1,0.05]

This is the end of the lists.