

Integration of Real and Monetary Sectors with Labor Market – SD Macroeconomic Modeling (3) –

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Abstract

This is the third paper of a series of macroeconomic modeling that tries to model macroeconomic dynamics on the basis of the principle of accounting system dynamics developed by the author. Money supply and creation processes of deposits were modeled in the first paper, while second paper built dynamic determination processes of GDP, interest rate and price level. In this paper, these two separate models are integrated to present a complete macroeconomic dynamic model consisting of real and monetary sectors. For its completion, population dynamics and labor market is additionally included. The integrated model is aimed to be generic, out of which diverse macroeconomic behaviors are shown to emerge. Specifically equilibrium growth path, business cycles and government debt issues are discussed in this paper.

1 Macroeconomic System Overview

This is the third paper of a series of macroeconomic modeling that tries to model macroeconomic dynamics. In the first paper [6], money supply and creation processes of deposits were modeled. Analytical method employed in the

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model is the principle of accounting system dynamics developed by the author [5]. For the analysis of money supply only three macroeconomic sectors were brought to attention; that is, central bank, commercial banks and non-financial sector as shown in Figure 1. In the second paper [7], dynamic determination

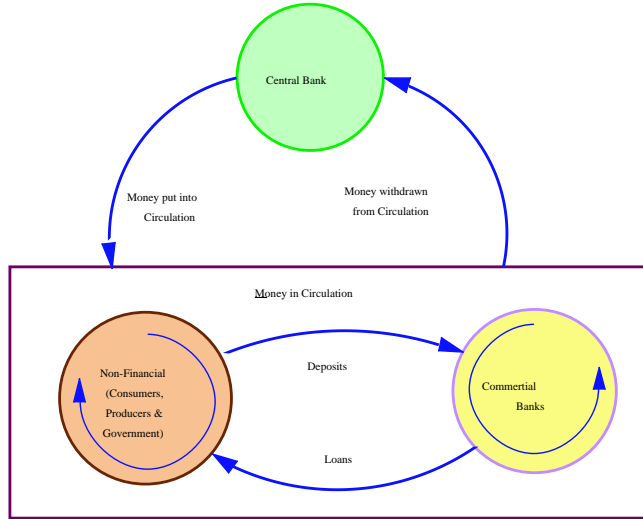


Figure 1: Three Sectors of Money Supply

processes of GDP, interest rate and price level were modeled on the same basis of the principle of accounting system dynamics. For this analysis four sectors of macroeconomy were introduced such as producers, consumers, banks and government.

This paper tries to integrate real and monetary sectors that have been so far analyzed separately in these two models. For this purpose, at least five sectors of macroeconomy, together with population and labor market, have to play macroeconomic activities simultaneously. Figure 2 illustrates an overview of such macroeconomic system and shows how these macroeconomic sectors interact with one another and exchange goods and services for money. Foreign sector is still excluded from the current analysis.

The reader will be reminded that the integrated model to be developed below is a generic one by its nature, and does not intend to deal with some specific issues our macroeconomy is currently facing. Once such a generic macroeconomic model is build, we believe, any specific macroeconomic issue could be challenged by bringing real data in concern to this generic model without major structural changes in this integrated model.

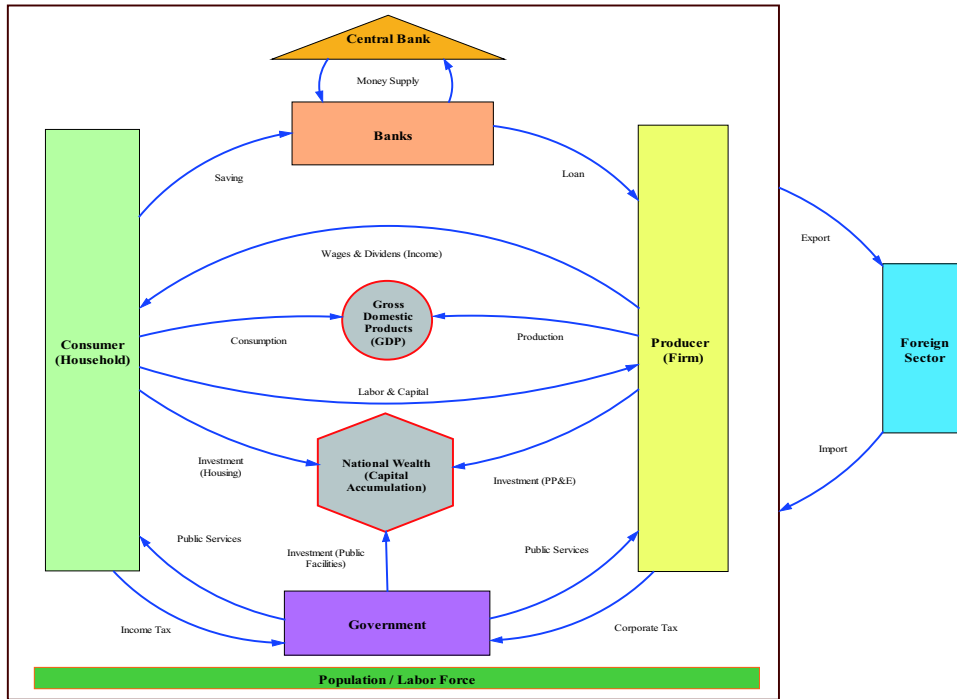


Figure 2: Macroeconomic System Overview

2 Changes in the model

Let us now start to explain some major changes made to the previous two models in order to integrate them.

Nominal and Real Units

In the previous models, all macroeconomic variables are assumed to have a dollar unit without specifically distinguishing nominal and real terms. In other words, GDP and other variables in the real sector of the previous model are implicitly interpreted as having real value of dollar.

In the integrated model of real and monetary sectors, variables in real production sector such as output and capital stock must have physical unit (which is specified as DollarReal in this paper), while all market transactions among all sectors are made in terms of nominal unit of money; that is, Dollar. To convert a physical unit to a monetary unit for transactions between real and monetary sectors, price P is used that has a unit of Dollar/DollarReal.

Interest Rate

With the introduction of real and nominal terms, interest rate introduced in the previous model has also to be reinterpreted as a real interest rate, meanwhile interest rate used for market transactions have to be nominal. The relationship between these two interest rates are shown by the following relation¹.

$$\text{Nominal interest rate} = \text{Real interest rate} + \text{Inflation rate} \quad (1)$$

Prime Rate

Due to the introduction of the central bank a portion of bank deposits have to be reserved as required reserve with the central bank. Accordingly, the amount of loans banks can make to producers becomes less than that of deposits from consumers, and, if the same interest rate is applied as in the previous model, their interest income from loans becomes less than their interest payment against deposits. To avoid this negatively retained earnings of the banks, a higher interest rate has to be applied to the loans, which is called here prime rate.

$$\text{Prime rate} > \text{Nominal interest rate} \quad (2)$$

The difference between these two interest rates is made large enough to avoid negatively retained earnings for banks. Moreover, it is assumed that positive earnings, if any, will be completely distributed among bank workers as consumers.

Money Supply and Demand

In our previous model, adjustment process of real interest rate is formalized as being determined by the excess real demand for money; that is, demand for money ($aY - bi$) less money supply M^s :

$$\frac{d i}{d t} = \Phi \left((aY - bi) - \frac{M^s}{P} \right) \quad (3)$$

where a is a fraction of income for transactional demand for money, and b is an interest sensitivity of demand for money. P is a price level and was treated as a sticky exogenous parameter.

This definition of demand for money may be no longer appropriate. The integrated model intends to be a complete system of macroeconomy, and money supply and demand for money have to be sought *within the system itself*.

Let us consider money supply first. In the previous model it is treated as exogenously fixed parameter, because there exists no mechanism to change money supply within the system.

¹This formulation is the so-called Fisher effect; to be precise, nominal rate of interest is the sum of real interest, inflation rate and their cross product. See [4, pp. 320-323] for the detailed discussion on the real rate of interest in relation with the uniform rate of profit.

The above behaviors are observed under a fixed money supply. It will be interesting to see how a change in money supply affects the behaviors of overall economy. To do so, however, our macroeconomic model here must be first of all integrated with the money supply model developed in my previous paper. Otherwise, it will be misleading to merely change money supply without examining its feedback relations within the system. [7]

With the introduction of the central bank, money supply is now created within the system. As defined in [6], money supply is here similarly defined as follows²:

$$\text{Money Supply} = \text{Currency in Circulation} + \text{Deposits} \quad (4)$$

Currency in circulation may be represented by the sum of cash stocks held by consumers, producers and government, while deposits are the amount of money consumers deposit with banks. For instance, whenever consumers purchase consumption goods from producers, the ownership of money changes hands from consumers to producers, and in the model this movement is represented as a decrease in consumers' stock of cash and a simultaneous increase in producers' stock of cash. In this way currency in circulation keeps moving among the cash stocks of consumers, producers and government, decreasing one cash stock and increasing another cash stock simultaneously.

On the other hand, demand for money consists of three motives: transaction, precautionary and speculative motives, according to the standard textbooks such as [2]. In our previous model (equation 3 above), real demand for money is formalized as consisting of transaction motives and speculative motives. Money demanded for market transactions in our integrated model is nothing but cash outflows by consumers, producers and government. Consumers need cash to buy consumption goods, and producers need cash to make investment. And these needs for transaction have to be met out of their cash stocks.

Demand for money (nominal) thus interpreted has a unit of dollar/year, while money supply as a stock of cash has a unit of dollar. Therefore, if the equation (3) is justified in SD model, demand for money has to be divided by a velocity of money, which has a unit of 1/year as illustrated in Figure 3³.

As to a speculative motive, demand for cash is assumed to move back and forth freely between deposits and cash stocks of consumers to maintain a certain level of currency ratio (= Cash / Deposits).

$$\text{Cash Demand} = \frac{\text{currency ratio} * \text{Deposits} - \text{Cash}}{\text{Cashing Time}} \quad (5)$$

²In our simple model, it may not be needed to classify monetary aggregates further into M1, M2 and M3.

³This part of treatment for demand and supply of money corresponds to the Quantity Equation:

$$\text{Money (M)} * \text{Velocity (V)} = \text{Price (P)} * \text{Transaction (T)}$$

V is call the transaction velocity of money in [3, p. 82].

Currency ratio in turn is assumed to be determined by nominal interest rate. Specifically, whenever nominal interest rate drops, currency ratio is made to rise so that consumers increase their demand for cash. As an extreme case if nominal interest rate drops to the level of a so-called liquidity trap (almost close to zero per cent in late 1990s in Japan), currency ratio is assumed to become one so that no deposits are made. In this way, speculative demand for cash is made dependent on the nominal interest rate in the model. Figure 3 illustrates our revised model of money supply and demand for money. It also shows adjustment processes of real interest rate and price level.

Cobb-Douglas Production Function

In the previous model, full capacity output level is specified as follows:

$$Y_{full} = \frac{1}{\theta} K \quad (6)$$

where θ is a capital-output ratio. In order to fully consider the role of employed labor L , it is replaced with a Cobb-Douglas production function:

$$Y_{full} = F(K, L, A) = AK^\alpha L^\beta \quad (7)$$

where A is a factor of technological change, and α and β are exponents on capital and labor, respectively.

With the introduction of the employed labor and totally available labor force, it also becomes possible to define potential output as

$$Y_{potential} = F(K, LF, A) = AK^\alpha LF^\beta \quad (8)$$

where LF is the total amount of labor force which is defined as the sum of the employed and unemployed labor. GDP gap, on which price change is made dependent, is now defined as the difference between potential GDP and desired output.

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

$$A = \bar{A}e^{\kappa t} \quad (9)$$

where κ is an annual increase rate of technological progress, which may be possible to be endogenously determined within the system. Following Nathan Forrester [1], let us also normalize this production function with the initial values:

$$\bar{Y}_{full} = F(\bar{K}, \bar{L}, \bar{A}) = \bar{A}\bar{K}^\alpha \bar{L}^\beta \quad (\text{Initial Output Level}) \quad (10)$$

Then, we have

$$Y_{full} = e^{\kappa t} \bar{Y}_{full} \left(\frac{K}{\bar{K}} \right)^\alpha \left(\frac{L}{\bar{L}} \right)^\beta \quad (11)$$

Now let us define profits after tax. In our integrated model, three types of taxes are levied: tax on production (excise tax), corporate tax and income

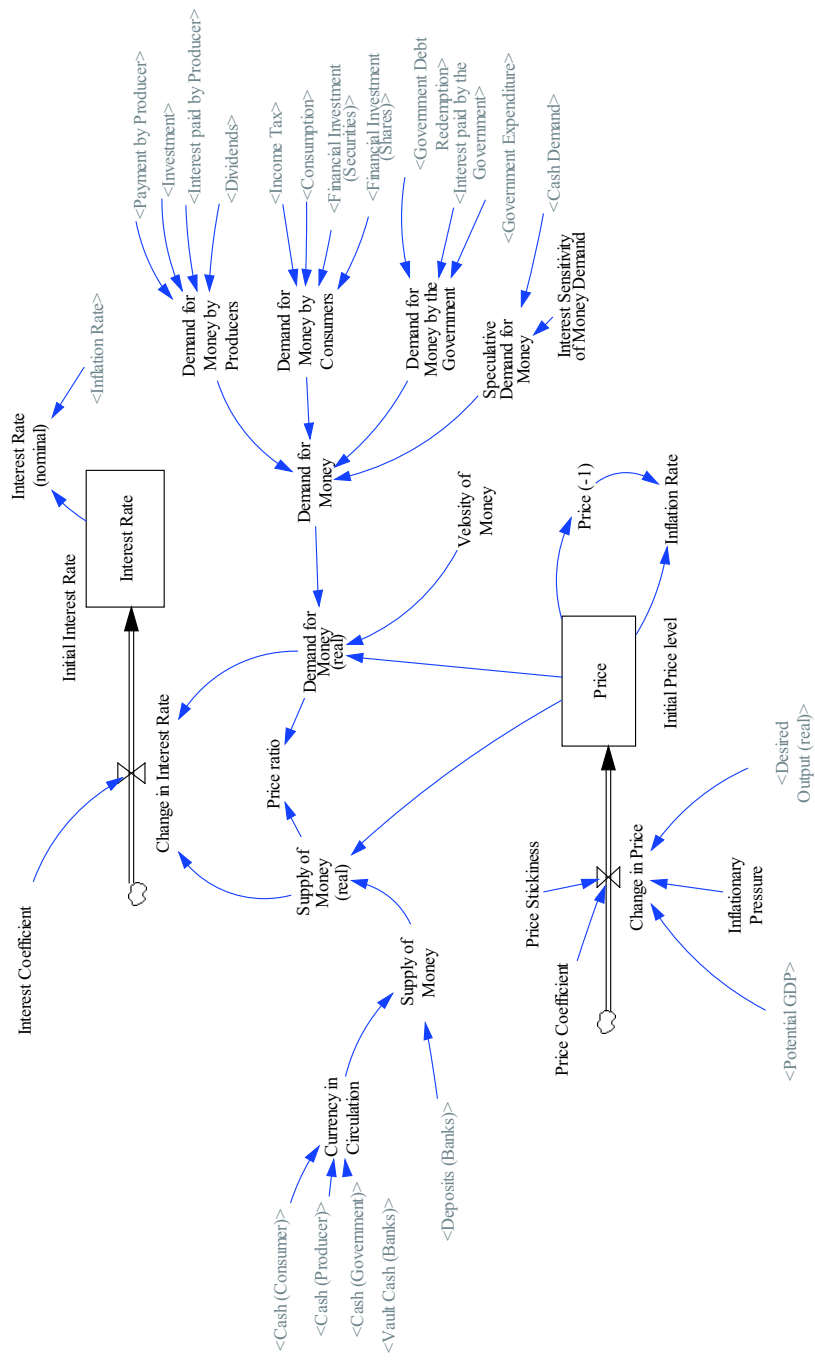


Figure 3: Money Supply and Demand

tax. The former two taxes are paid by producers (Figure 6), while income tax, consisting of lump-sum tax and a proportional part of income tax, is paid by consumers (Figure 7). With these into consideration, profits after tax Π are now defined as

$$\Pi = ((1 - t)PY_{full} - (i + \delta)P_K K - wL)(1 - t_c) \quad (12)$$

where t is an excise tax rate, t_c is a corporate profit tax rate, i is a real interest rate, δ is a depreciation rate, and w is a nominal wage rate.

One remark may be appropriate for the definition of capital cost $iP_K K$. The amount of capital against which interests are paid are the amount of debt outstanding by producers (which is the same as the outstanding loan by banks) in the integrated model, yet at an abstract theoretical level it is regarded the same as the book value of capital from which depreciation is deducted. Our model based on double accounting system enables to handle this distinction. Specifically, capital cost (= interest paid by producers) are calculated in the model as

$$iP_K K \approx \text{Prime Rate} \times \text{Loan (or Debt by producers)} \quad (13)$$

First order condition for profit maximization with respect to capital stock is calculated by partially differentiating profits with respect to capital as

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

The demand function for capital is thus obtained as

$$K = \frac{\alpha(1 - t)PY_{full}}{(i + \delta)P_K} \quad (15)$$

At a macroeconomic level of one commodity, price of output P is treated with 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

$$K^*(i) = \frac{\alpha(1 - t)Y^*}{i + \delta} \quad (16)$$

In our model desired output Y^* is represented by the variable: Aggregate Demand Forecasting (Long-run) as illustrated in Figure 4 (see also [1]).

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

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

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

$$\theta^*(i) = \frac{K^*}{Y^*} = \frac{\alpha(1-t)}{i + \delta} \quad (18)$$

Then, the above investment function can be rewritten as⁴

$$I(i) = \frac{(\theta^*(i) - \theta)Y^*}{\text{Time to Adjust Capital}} + \delta K \quad (19)$$

The new investment function obtained above replaces our previous investment function that is determined by the interest rate:

$$I(i) = I_0 - ai \quad (20)$$

where a is an interest sensitivity of investment.

First order condition for profit maximization with respect to labor is calculated as follows:

$$\begin{aligned} \left(\frac{1}{1-t_c} \right) \frac{\partial \Pi}{\partial L} &= \beta(1-t)Pe^{\kappa t} \left(\frac{\bar{Y}_{full}}{\bar{L}} \right) \left(\frac{K}{\bar{K}} \right)^\alpha \left(\frac{L}{\bar{L}} \right)^{\beta-1} - w \\ &= \frac{\beta(1-t)Pe^{\kappa t} \left(\frac{\bar{Y}_{full}}{\bar{L}} \right) \left(\frac{K}{\bar{K}} \right)^\alpha \left(\frac{L}{\bar{L}} \right)^\beta}{\frac{L}{\bar{L}}} - w \\ &= \frac{\beta(1-t)PY_{full}}{L} - w \\ &= 0 \end{aligned} \quad (21)$$

Demand for labor is thus obtained as

$$L = \frac{\beta(1-t)PY_{full}}{w}, \quad (22)$$

and the amount of wages to be paid by producers is determined by

$$W = wL = \beta(1-t)PY \quad (23)$$

as illustrated in Figure 6. Nominal wage rate is thus calculated as $w = W/L$.

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

$$L^* = \frac{\beta(1-t)PY^*}{w^e} \quad (24)$$

⁴To be precise, this reformulation cannot be used as an alternative investment function without minor behavioral changes. Hence equation (17) is used in this model.

In the integrated model, Y^* is represented by the variable: Desired Output (real), while the expected wage rate is calculated as a product of wage rate, inflation rate and a desired wage rate increase as illustrated in Figure 5. When a desired wage increase is unitary, the expected rate of wage becomes proportional to the inflation rate so that real wage rate is held constant. A desired wage increase will be determined by the demand and supply of labor in the labor market. Specifically, it is defined as a table function of unemployment rate. When unemployment decreases, the desired wage increase jumps to as high as 10 times. When unemployment is 3%, it is assumed to be unitary, and gradually begin to decline as unemployment becomes higher.

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

$$L^d(Y^*, w^e) = \frac{L^* - L}{\text{Time to Adjust Labor}} \quad (25)$$

Labor demand thus defined has a downward-sloping shape such that

$$\frac{L^d}{w^e} = -\frac{\beta(1-t)PY^*}{\text{Time to Adjust Labor}} \frac{1}{(w^e)^2} < 0. \quad (26)$$

With the above first-order conditions, profits after tax are now rewritten as

$$\begin{aligned} \Pi &= ((1-t)PY_{full} - (i + \delta)P_K K - wL)(1-t_c) \\ &= ((1-t)PY_{full} - \alpha(1-t)PY_{full} - \beta(1-t)PY_{full})(1-t_c) \\ &= (1-t)(1-t_c)(1-\alpha-\beta)PY_{full} \end{aligned} \quad (27)$$

Hence, if constant returns to scale is assumed as production technology, as often done; that is, $\alpha + \beta = 1$, 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 $\alpha + \beta < 1$.

Labor Market

So far labor demand is assumed to be fully met as the equation (25) indicates. To make the story more realistic, it is necessary to introduce the availability of labor supply, and the population dynamics of the economy by which labor supply is constrained.

Population dynamics is modeled according to the World3 model (whose Vensim version is provided as one of the sample models by its vendor: Ventana Systems, Inc.). It consists of five cohorts of age groups, and two population cohorts between age 15 and 64 are considered to be a productive population cohort.

In this integrated model, the productive population cohort is further broken down into five categorically-different subgroups: high school, college education, voluntary employed, employed labor, and unemployed labor, as illustrated by

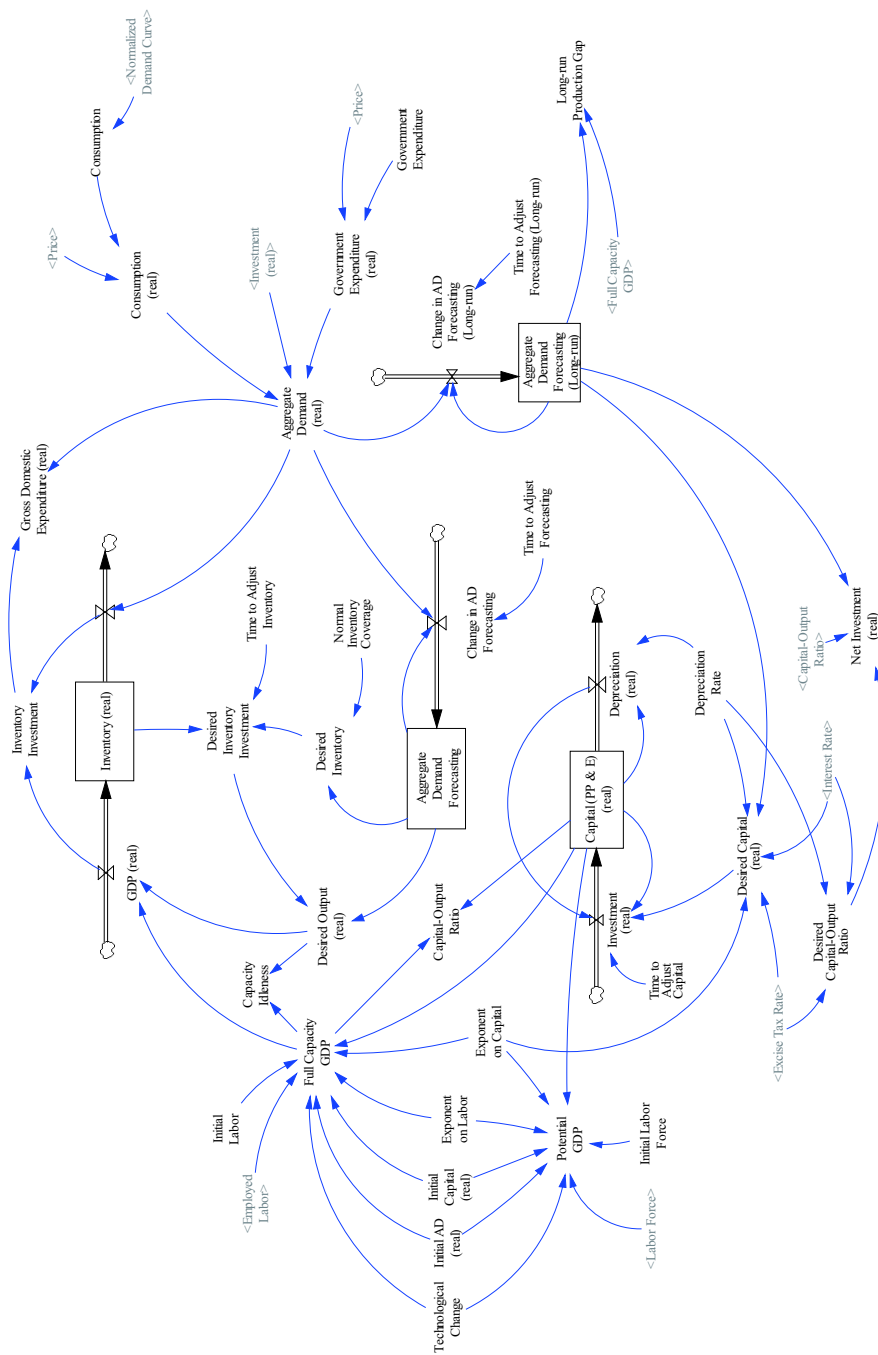


Figure 4: Real Production of GDP

Figure 5. Employed and unemployed labor constitutes a total labor force, by which potential GDP is calculated together with the amount of capital.

As already discussed above, whenever labor market becomes tight and unemployment rate approaches to zero, a desired wage rate w^e will increase, causing demand for labor to decrease in equation(24). It decreases as the unemployment rate increases, causing the demand for labor to increase.

3 Transactions Among Five Sectors

Let us now describe some transactions by the central bank that is additionally included in this model. For the convenience to the reader, let us also repeat some of the transactions, with some revisions, by producers, consumers, government and banks that were already presented in our previous model.

Producers

Major transactions of producers are, as illustrated in Figure 6, summarized as follows.

- Out of the GDP revenues producers pay excise tax, deduct the amount of depreciation, and pay wages to workers (consumers) and interests to the banks. The remaining revenues become profits before tax.
- They pay corporate tax to the government out of the profits before tax.
- The remaining profits after tax are paid to the owners (that is, consumers) as dividends.
- Producers are thus constantly in a state of cash flow deficits. To continue new investment, therefore, they have to borrow money from banks and pay interest to the banks.

Consumers

Transactions of consumers are illustrated in Figure 7, some of which are summarized as follows.

- Consumers receive wages and dividends from producers.
- Financial assets of consumers consist of bank deposits and government securities, against which they receive financial income of interests from banks and government. (In this paper, no corporate shares are assumed to be held by consumers).
- In addition to the income such as wages, interests, and dividends, consumers receive cash whenever previous securities are partly redeemed annually by the government.

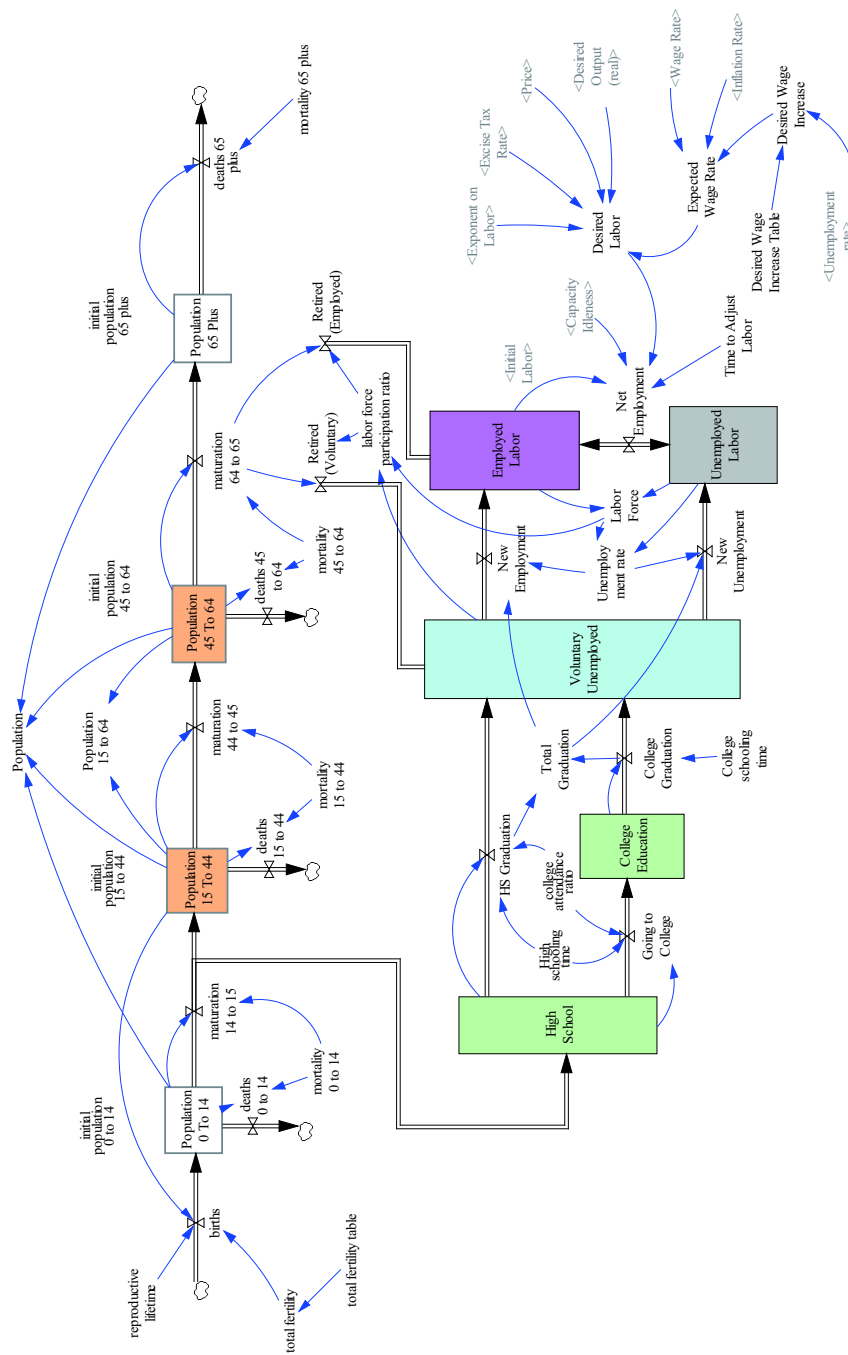


Figure 5: Population and Labor Market

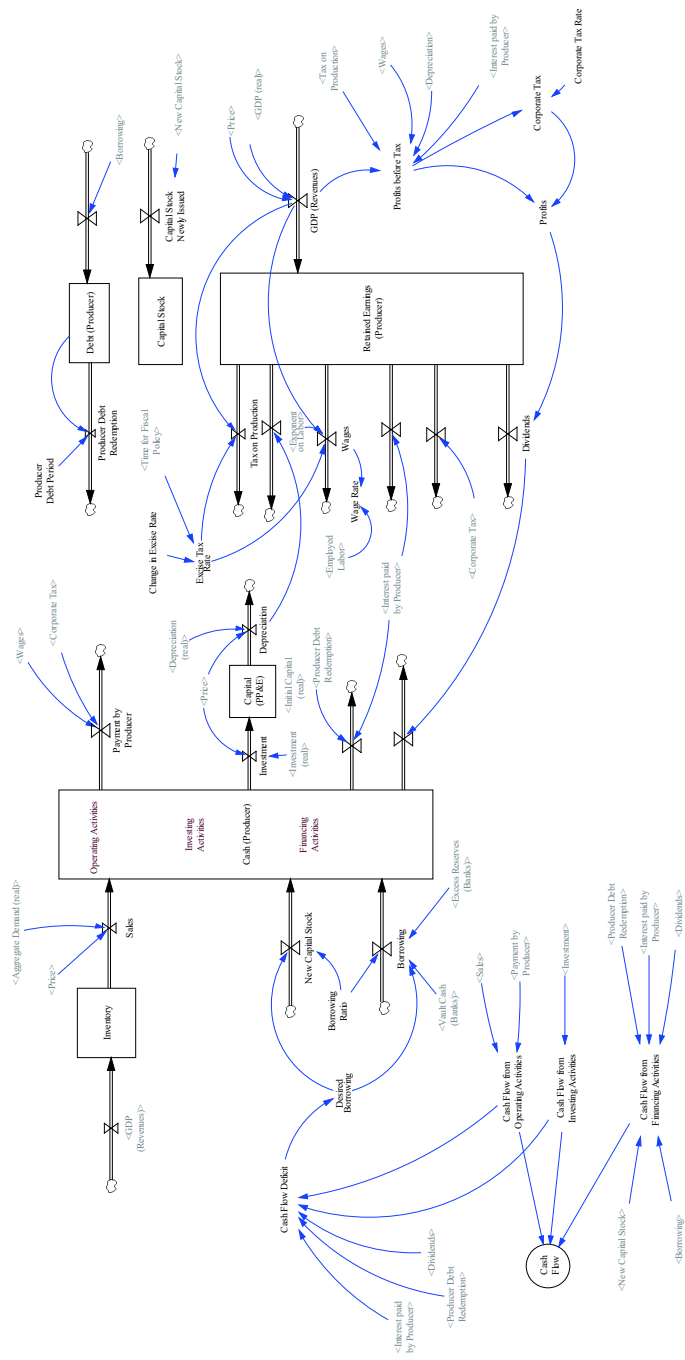


Figure 6: Transactions of Producers

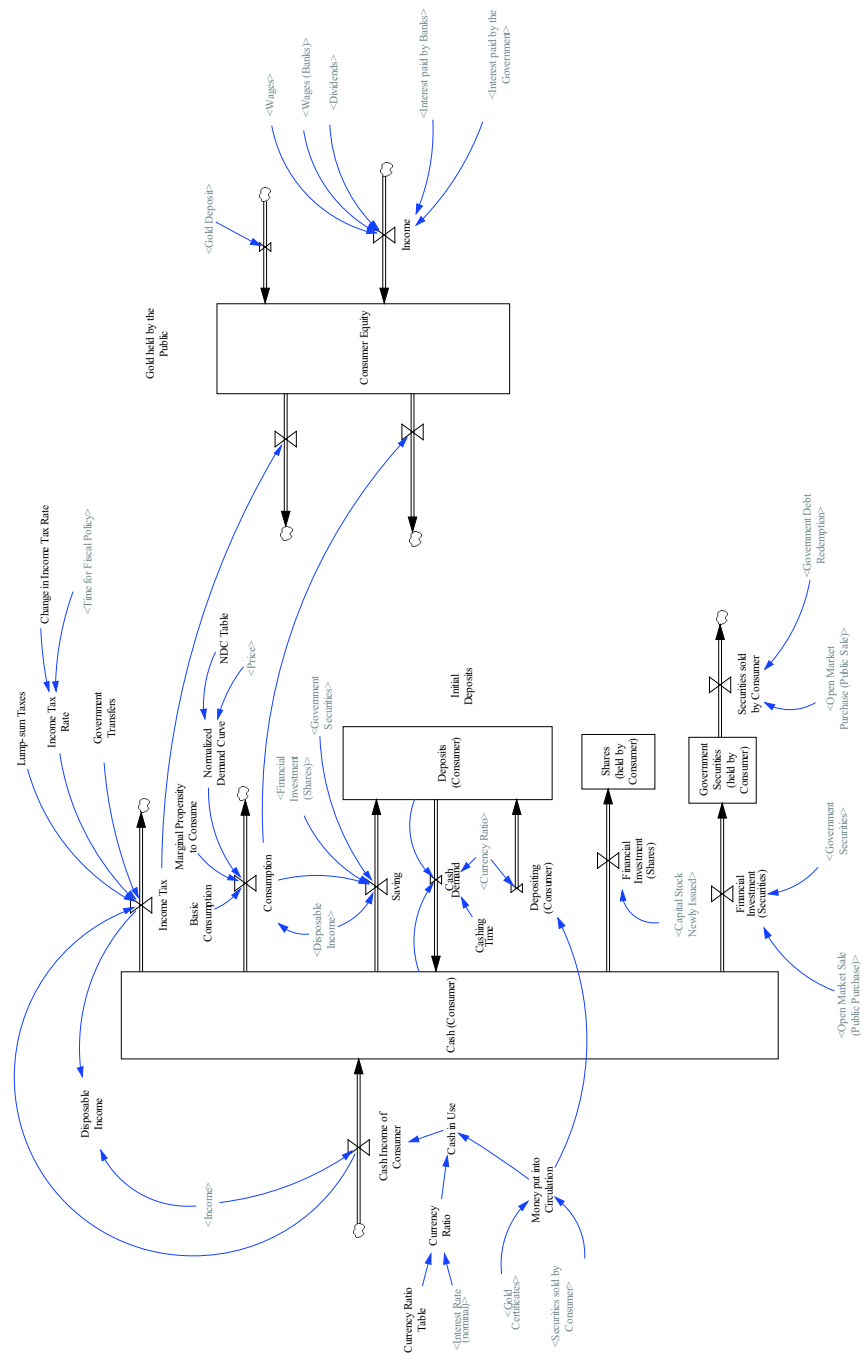


Figure 7: Transactions of Consumer

- Out of these cash income as a whole, consumers pay income taxes, and the remaining income becomes their disposal income.
- Out of their disposal income, they spend on consumption. The remaining amount are either spent to purchase government securities or saved.

Government

Transactions of the government are illustrated in Figure 8, some of which are summarized as follows.

- Government receives, as tax revenues, income taxes from consumers and corporate taxes from producers.
- Government spending consists of government expenditures and payments to the consumers for its partial debt redemption and interests against its securities.
- 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 cash from consumers by newly issuing government securities.

Banks

Transactions of banks are illustrated in Figure 9, some of which are summarized as follows.

- Banks receive deposits from consumers, against which they pay interests.
- They are obliged to deposit a portion of the deposits as the required reserves with the central bank.
- Out of the remaining deposits loans are made to producers and banks receive interests for which a prime rate is applied.
- Their retained earnings thus become interest receipts from producers less interest payment to consumers. Positive earning will be distributed among bank workers as consumers.

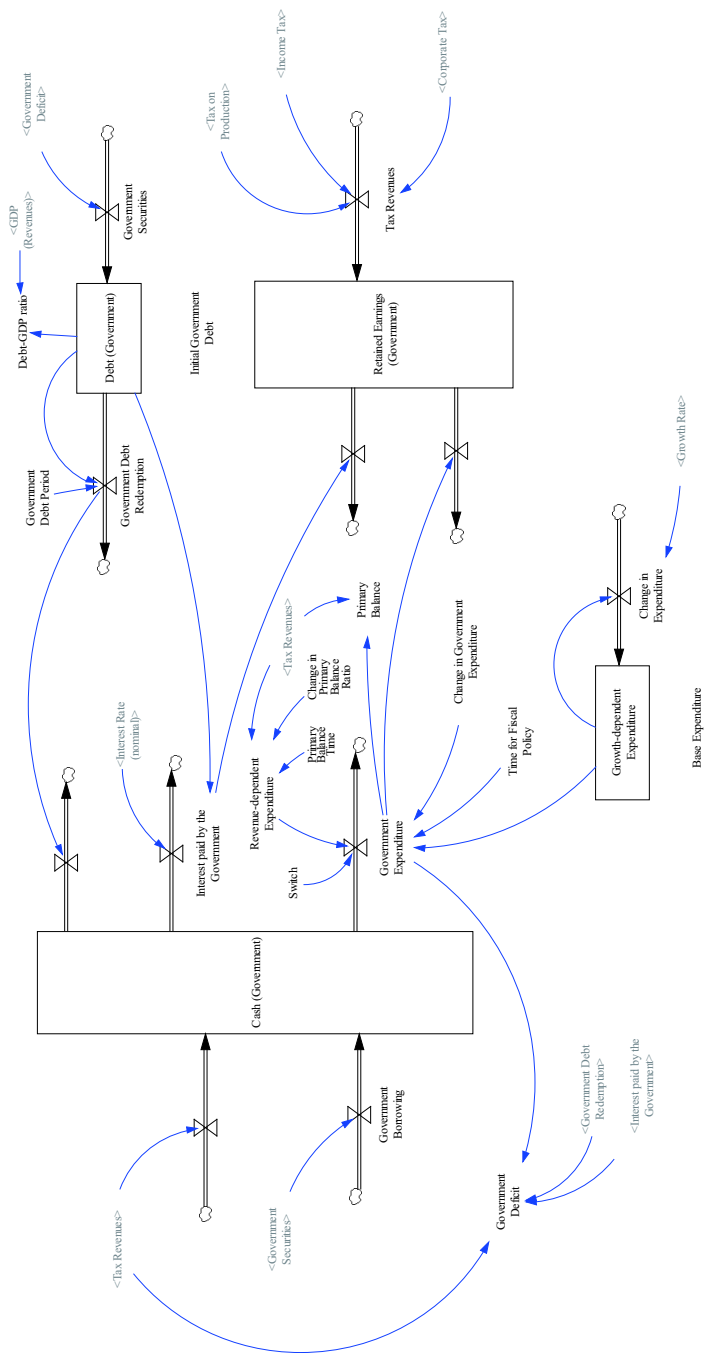


Figure 8: Transactions of Government

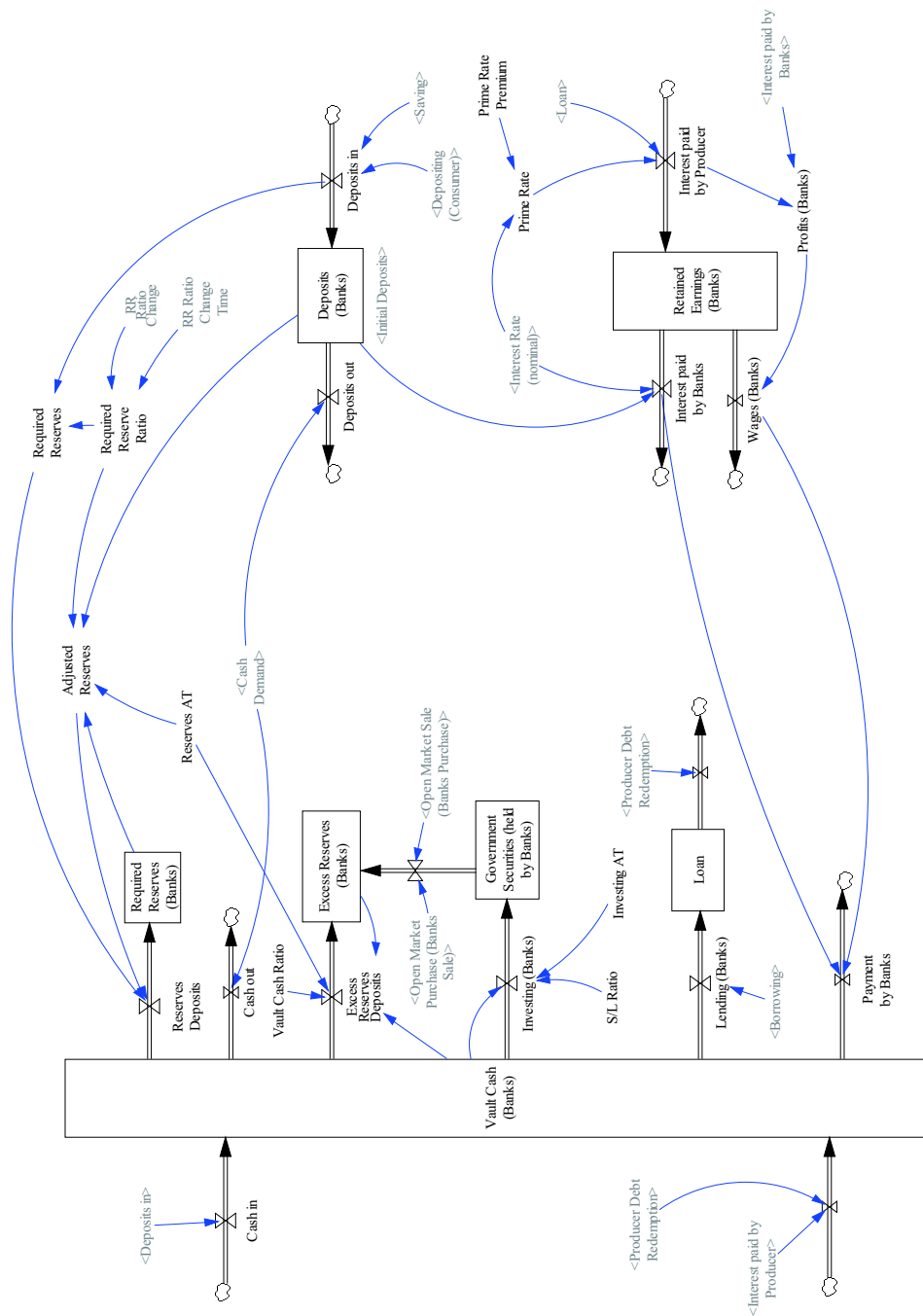


Figure 9: Transactions of Banks

Central Bank

In the integrated model, central bank plays a very important role of providing a means of transactions and store of value; that is, currency. To make a story simple, its sources of assets against which currency is issued are confined to gold and government securities. The central bank can control the amount of money supply through the amount of monetary base consisting of currency outstanding and reserves over which it has a direct power of control. This is done through monetary policies such as the manipulation of required reserve ratio and open market operations.

Transactions of the central bank are illustrated in Figure 10, some of which are summarized as follows.

- The central bank issues currencies against the gold deposited by the public.
- It can also issue currency by accepting government securities through open market operation, specifically by purchasing government securities from consumers.
- It can similarly withdraw currencies by selling government securities to the public.
- 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 control the monetary base directly.

4 Behaviors of the Integrated Model

Equilibrium in the Real Sector

The integrated model is now complete. It is a generic model, out of which diverse macroeconomic behaviors will be produced. Let us start with an equilibrium growth path of the macroeconomy. In the previous model, Keynesian aggregate demand equilibrium is defined as an equilibrium state where aggregate demand is equal to production. Moreover, it is also emphasized that the Keynesian aggregate demand equilibrium is not a full capacity equilibrium.

It is now clear that the Keynesian theory of aggregate demand equilibria is imperfect from a SD model-building point of view, because price level is assumed to be sticky and there exists no built-in mechanism to restore a full capacity production equilibrium unless monetary and fiscal policies are carried out. [7]

Let us call an equilibrium state a *full capacity aggregate demand equilibrium* if the following three output and demand levels are met:

$$\text{Full Capacity GDP} = \text{Desired Output} = \text{Aggregate Demand} \quad (28)$$

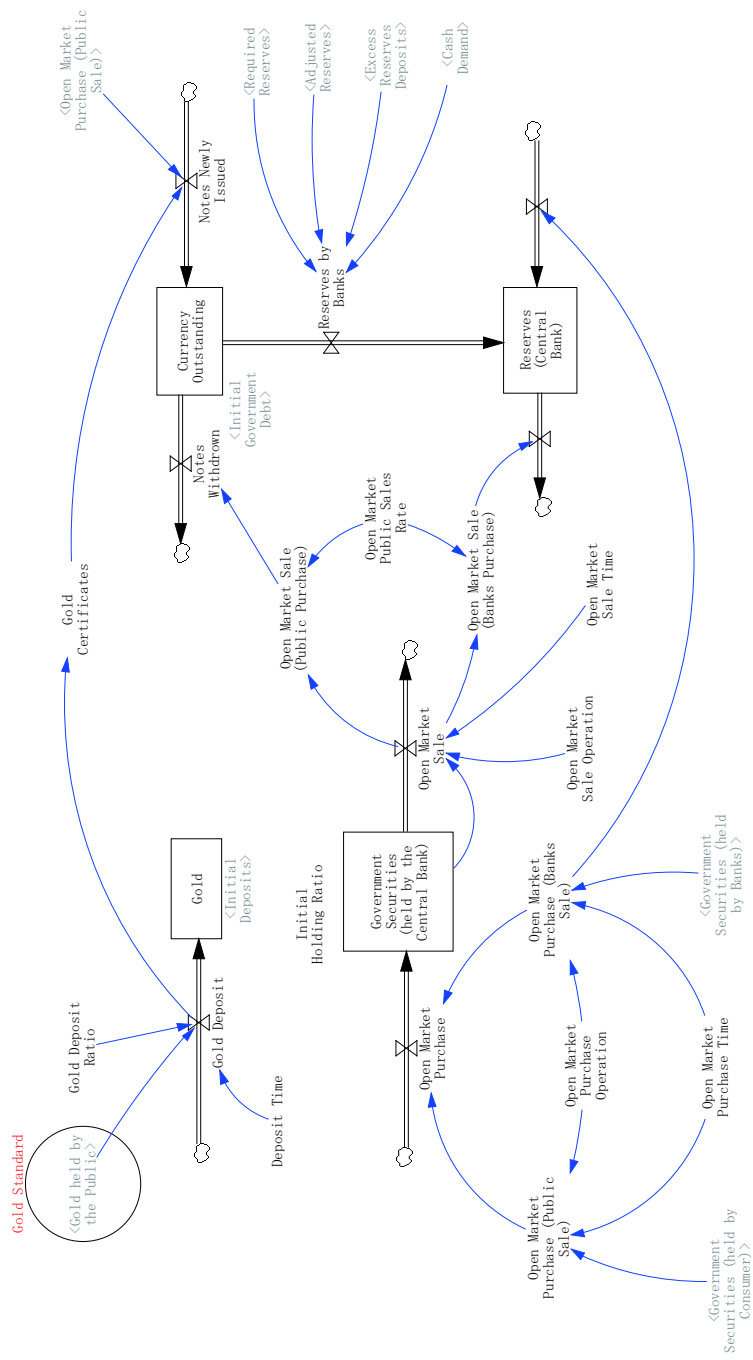


Figure 10: Transactions of Central Bank

In the upper diagram of Figure 11, full capacity GDP, GDP and aggregate demand are represented by green, blue and red lines, respectively. Our integrated model can successfully produce such a growth path of full capacity aggregate demand equilibrium up to the year around 20, followed by the similar length of under capacity growth path, then again an equilibrium path. Economic growth rates fluctuates between -1.8% and 3.7% over the 50 years, as shown in the upper diagram. Let us call such a period of under capacity growth *lost decades*.

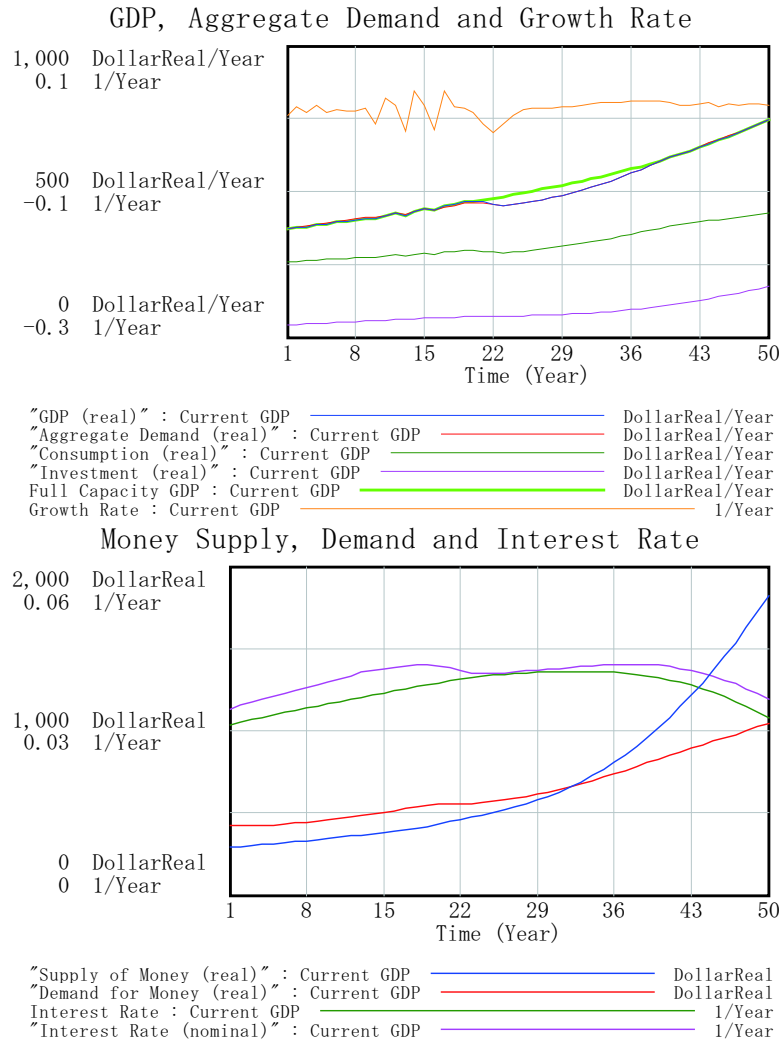


Figure 11: Full Capacity Aggregate Demand Equilibria

Why can the economy not sustain its full capacity equilibrium growth path? The lower diagram in Figure 11 illustrates that demand for money is greater than

the money supply up to the year around 33, and nominal and real interest rate continue to grow, though very slowly, beyond that year a little bit ahead, then begin to fall eventually. This implies that even under a full capacity equilibrium monetary sector has not been in the state of equilibrium, and this disequilibrium state of monetary sector might eventually have triggered the lost decades. At this stage of research, an attempt to produce a true equilibrium growth path both in real and monetary sectors has been unsuccessful.

Monetary and Fiscal Policies for Equilibrium

Can we, then, vanquish the lost decades disequilibria? Fortunately, it is possible with the application of fiscal and monetary policies in our integrated model. Let us consider monetary policy, first. Suppose the central bank, predicting the lost decades in advance, increases the purchase of government securities by 5% at the year 8, instead of the original set of 3% at the year 2 (See the top left diagram of Figure 12). Then, money supply continues to grow gradually, and interest rate eventually starts to decrease around the year 27 (see top right and bottom left diagrams.). These changes in the monetary sector will eventually prevent the lost decades from taking place, and full capacity aggregate demand equilibrium can be sustained for the entire 50 years (see the bottom right diagram).

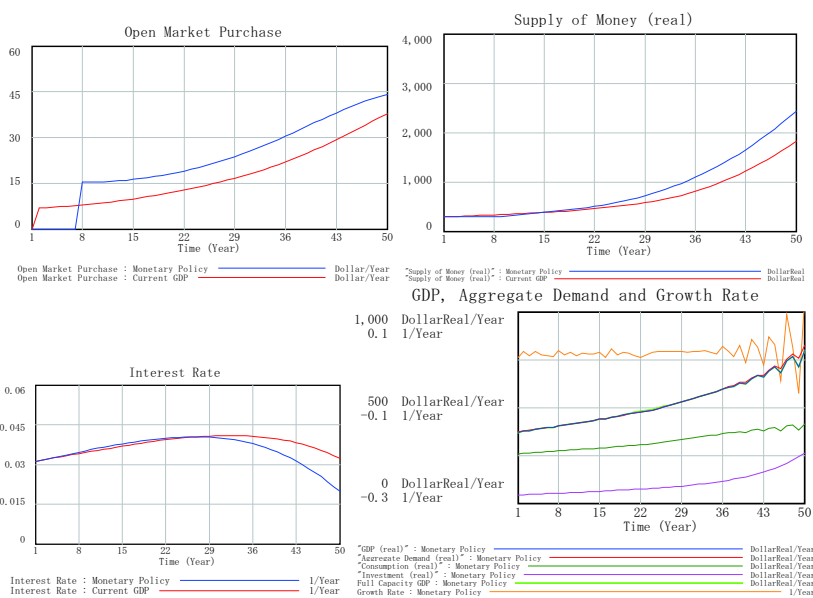


Figure 12: Monetary Policy: Open Market Purchase and GDP

Second scenario of eliminating the lost decades is to apply fiscal policy. Facing the beginning of the lost decades, the government decides to introduce an increase in income tax rate by 5%; that is, from the original 10% to 15 %, at

the year 21 (See left hand diagram in Figure 13). Under the assumption of balanced budget, or a unitary primary balanced ratio, an increase in income tax also becomes the same amount of increase in government expenditure. Eventually, aggregate demand is stimulated to overwhelm the lost decades (see right hand diagram). In this way, our integrated generic model can provide effective scenarios of sustaining full capacity aggregate demand equilibrium growth path through monetary and fiscal policies.

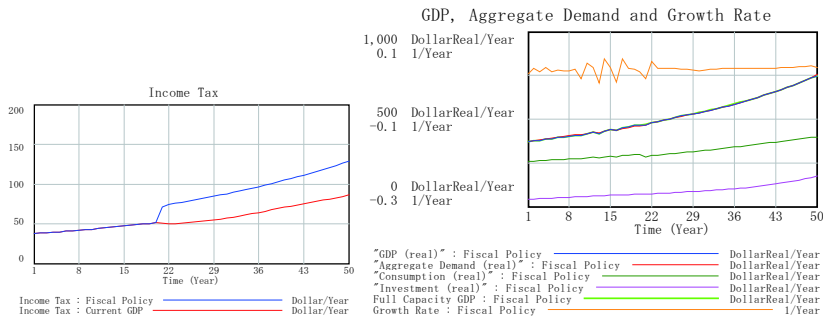


Figure 13: Fiscal Policy: Change in Income Tax Rate under Balanced Budget

Business Cycles by Inventory Coverage

From now on, let us assume the full capacity equilibrium path that is attained by the above fiscal policy as a starting state of the economy for analysis. One of the interesting questions is to find out a macroeconomic structure that may produce economic fluctuations or business cycles. How can the above equilibrium growth path be broken and business cycles will be triggered?

Our integrated model can successfully produce at least two ways of causing macroeconomic fluctuations. Firstly, they can be caused by increasing normal inventory coverage period, which is originally set to zero, to 0.4 year (about 5 months), and decreasing the time to adjust inventory from 0.6 year to 0.4 year. Business cycles thus triggered have a cycle period of about 8 to 20 years as illustrated in Figure 14.

Business Cycles by Price Fluctuation

Secondly, the equilibrium growth path can also be broken and business cycle is triggered, though, in a totally different fashion. This time let us assume that a price response to the excess demand for products becomes more sensitive so that its price adjustment coefficient increases from the original value of 0.03 to 0.185. Then a quite regular business cycle with a cycle period of about 10 years can be caused as shown in Figure 15.

Additionally, Figure 16 illustrates the fluctuations of price, nominal wage rate and unemployment rate. It is interesting to observe that price and wage rate

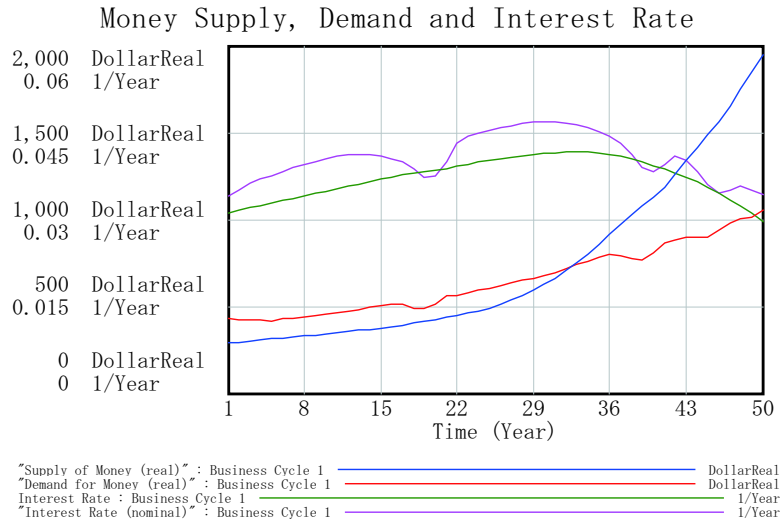
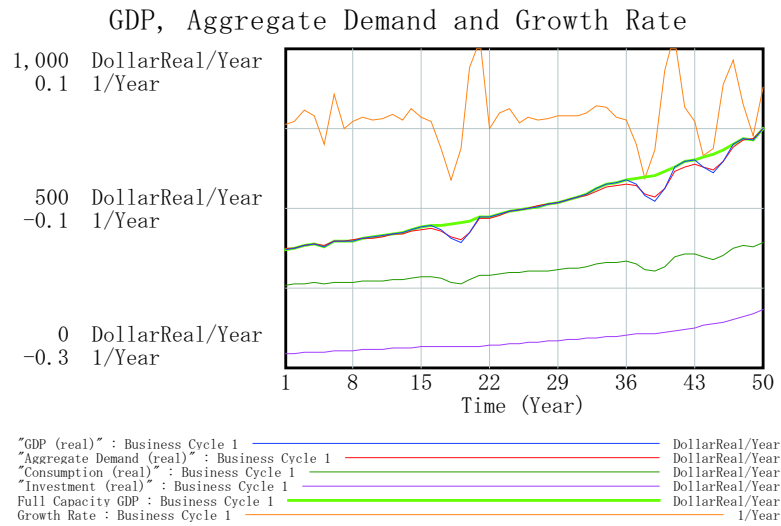


Figure 14: Business Cycles triggered by Inventory Coverage Increases

fluctuate in the same direction, while unemployment rate fluctuates counter-cyclically. In other words, when price and wage rate increases, unemployment rate decreases, and vice versa.

In this way, two similar business cycles are triggered, out of the same equilibrium growth path, by two different causes; one by an increase in inventory coverage period, and the other by the sensitivity of price changes. The ability to produce these different behaviors of business cycles and economic fluctuations indicates a richness of our integrated generic model.

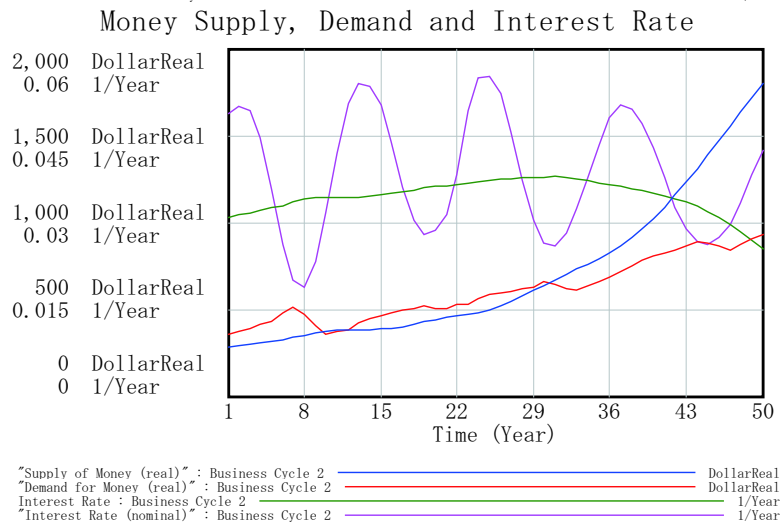
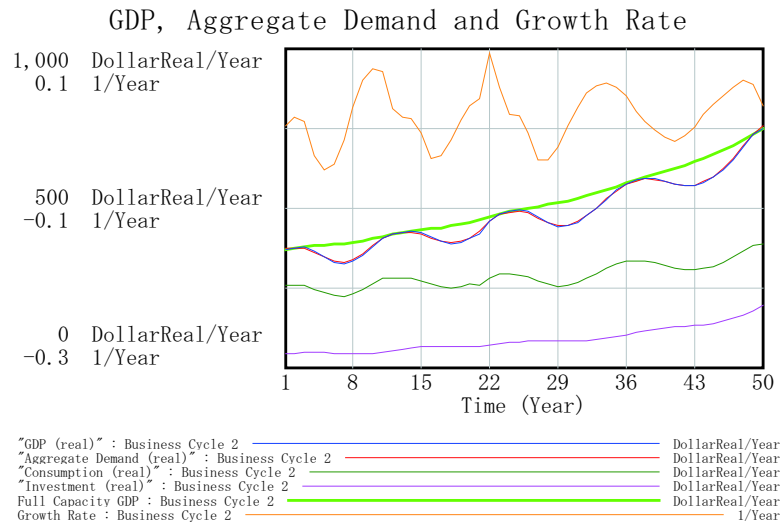


Figure 15: Business Cycles triggered by the Increase in Price Sensitivity

Government Debt

So long as the equilibrium path in the real sector is attained, no macroeconomic problem seems to exist. Yet behind the full capacity aggregate demand growth path attained in Figure 13, government debt continues to accumulate as Figure 17 illustrates. Primary balance ratio is initially set to one and balanced budget is assumed in our model; that is, government expenditure is set to be equal to tax revenues. Why, then, does the government continue to suffer from the current deficit?

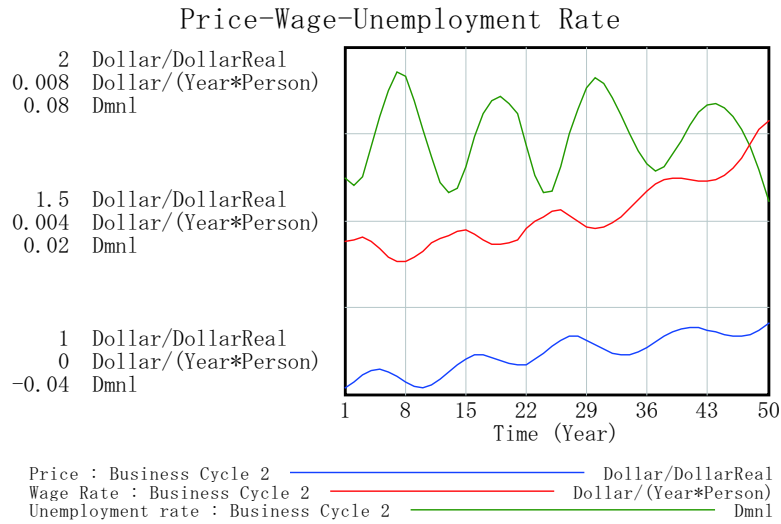


Figure 16: Price, Wage Rate and Unemployment Rate

In the model government deficit is defined as

$$\text{Deficit} = \text{Tax Revenues} - \text{Expenditure} - \text{Debt Redemption} - \text{Interest} \quad (29)$$

Therefore, even if balanced budget is maintained, the government still has to keep paying its debt redemption and interest. This is why it has to keep borrowing and accumulating its debt. Initial GDP in the model is assumed to be 368, while government debt is initially set to be 300. Hence, the initial debt-GDP ratio is around 0.8 year (a slightly higher than the current ratios among EU countries). The ratio continues to increase to 2.6 years at the year 50 in the model (see the red line in the left diagram of Figure 18 below). This implies the government debt becomes 2.6 times as high as the annual level of GDP.

Can such a high debt be sustained? Absolutely no. Eventually this runaway accumulation of government debt may cause nominal interest rate to increase, because the government may be forced to pay higher and higher interest rate in order to keep borrowing, which may in turn launch a hyper inflation⁵.

On the other hand, a higher interest rate may trigger a sudden drop of government security price, deteriorating the value of financial assets of banks, producers and consumers. The devaluation of financial assets may force some banks and producers to go bankrupt eventually. In this way, under such a hyper inflationary circumstance, financial crisis becomes inevitable and government is destined to collapse. This is one of the hotly debated scenarios about the consequences of the abnormally accumulated debt in Japan, whose current debt-GDP ratio is about 1.8 years; the highest among OECD countries!

⁵This feedback loop from the accumulating debt to the higher interest rate is not yet fully incorporated in the model.

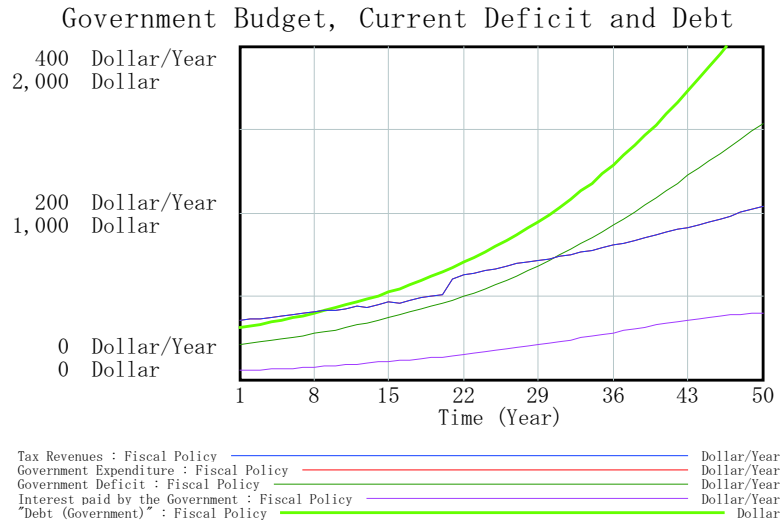


Figure 17: Accumulation of Government Debt

Let us now consider how to avoid such a financial crisis and collapse. At the year 21 when fiscal policy is introduced to restore a full capacity aggregate demand equilibrium in the model, the economy seems to have gotten back to a right track of sustained growth path. And most macroeconomic textbooks emphasize this positive side of fiscal policy. A negative side of fiscal policy is the accumulation of debt for financing the government expenditure. Yet most macroeconomic textbooks neglect or less emphasize this negative side, partly because their macroeconomic framework cannot handle this negative side effect properly as our integrated model does here. In our example the debt-GDP ratio is 1.34 years at the introduction year of fiscal policy. It is already a very high level.

At the face of financial crisis as discussed above, suppose that the government is forced to reduce its debt-GDP ratio to around one year by the year 50, though this is a still high level compared to the current ratios among EU countries. To attain this goal, a primary balance ratio has to be reduced to 0.8 in our economy. In other words, the government has to make a strong commitment to repay its debt annually by the amount of 20 percent of its tax revenues. Let us assume that this reduction is put into action around the same time when fiscal policy is introduced. Under such a radical financial reform, as illustrated in Figure 18, debt-GDP ratio will be reduced to around one year (blue line in the left diagram) and the accumulation of debt (green line in the right diagram) will be eventually curved.

Even so, this radical financial reform becomes very costly to the government and its people as well. At the year of the implementation of 20 % reduction of a primary balance ratio, growth rate is forced to drop to minus 12 %, and the economy fails to sustain a full capacity aggregate demand equilibrium as

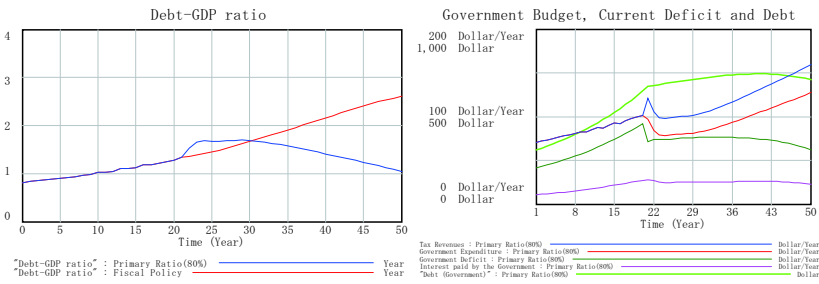


Figure 18: Government Debt Deduction

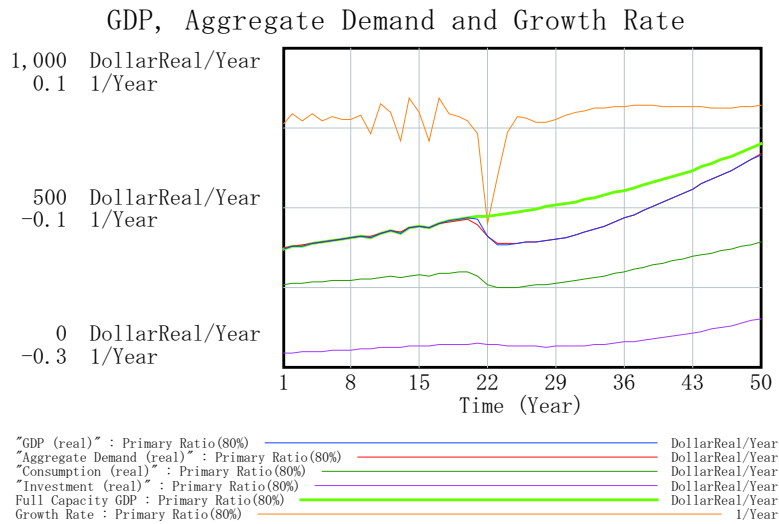


Figure 19: Reduction of Government Debt

illustrated in Figure 19. In other words, the reduction of the primary balance ratio by 20% nullifies the attained full capacity aggregate demand equilibrium by fiscal policy. In the left diagram of Figure 20 the middle dark green line illustrates the original growth path and the top red line denotes a full capacity growth path enabled by the fiscal policy. Meanwhile, the bottom blue line shows the under capacity growth path implemented by the reduction of the primary balance ratio, which obviously reverses the attained full capacity growth path. On the other hand, in the right diagram of the Figure the middle dark green line illustrates the original unemployment rate and the bottom red line denotes the rate under a full capacity growth path. Meanwhile, the top blue line indicates the unemployment rate caused by the 20% reduction of the primary balance ratio, which sooner or later reaches as high as almost 9% at the year 29, then gradually begin to decrease to 4%.

In this way, the reduction of the government debt by diminishing a primary

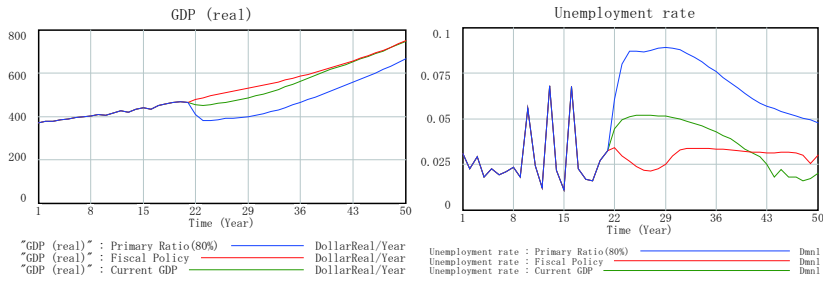


Figure 20: Comparison of Three Growth Paths and Unemployment Rates

balance ratio is shown to be a very painful process. Yet, a financial reform of this radical type seems to allude to the only soft-landing solution path for a country with a serious debt problem such as Japan, so long as our SD simulation suggests, if a sudden collapse of the government and macroeconomy is absolutely to be avoided. Its success depends on how people can endure getting *worse before better*.

5 Conclusion

The integration of the real and monetary sectors in macroeconomy is attained from the previously developed two macroeconomic models. For this integration, five macroeconomic sectors are brought to the model such as producers, consumers, government, banks and the central bank, together with population and labor market. Moreover, several major changes are made to the previous models, among which distinction between nominal and real outputs and interest rates are the most crucial one. Another improvement is an introduction of Cobb-Douglas production function that enables a formation of new investment function and labor demand.

The integrated macroeconomic model could be generic in the sense that diverse macroeconomic behaviors will be produced within the same model structure. To show such a capability, some macroeconomic behaviors are discussed in this paper. First, the existence of a full capacity aggregate demand equilibrium growth path is demonstrated, side by side with the applications of monetary and fiscal policies. Then, business cycles are triggered out of the equilibrium path, by two different causes; inventory coverage period and price sensitivity. Finally accumulating government debt issue is explored. As shown by these, we believe the integrated generic model presented here will provide a foundation for the analysis of diverse macroeconomic behaviors.

To make the model furthermore complete, however, at least the following two fine-tuning revisions have to be incorporated to the model: (1) a feedback loop of the accumulating government debt to the interest rate, and (2) more detailed process of determining wage rate in the labor market. With these two revisions to be fully implemented, our next and final paper in this series of

macroeconomic modeling will be to open the integrated model to foreign sector.

References

- [1] Nathan B. Forrester. *A Dynamic Synthesis of Basic Macroeconomic Theory: Implications For Stabilization Policy Analysis*. Ph.D. Thesis, D-3384, System Dynamics Group, Sloan School of Management, MIT, 1982.
- [2] E. Robert Hall and B. John Taylor. *Macroeconomics*. W.W. Norton & Company, New York, 5th edition, 1997.
- [3] N. Gregory Mankiw. *Macroeconomics*. Worth Publishers, New York, 5th edition, 2003.
- [4] Kaoru Yamaguchi. *Beyond Walras, Keynes and Marx – Synthesis in Economic Theory Toward a New Social Design*. Peter Lang Publishing, Inc., New York, 1988.
- [5] Kaoru Yamaguchi. Principle of accounting system dynamics – modeling corporate financial statements –. In *The 21st International Conference of the System Dynamics Society*, New York, 2003. System Dynamics Society.
- [6] Kaoru Yamaguchi. Money supply and creation of deposits : SD macroeconomic modeling (1). In *22nd International Conference of the System Dynamics Society*, Oxford, England, 2004. The System Dynamics Society.
- [7] Kaoru Yamaguchi. Aggregate demand equilibria and price flexibility : SD macroeconomic modeling (2). In *23rd International Conference of the System Dynamics Society*, Boston, USA, 2005. The System Dynamics Society.