Asset Portfolio Choice of Banks and Inflation Dynamics (Preliminary)

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Abstract

Since the middle of 1990s, the Japanese banks have drastically tilted their asset portfolio towards the government bond holding, reducing the lending to the firms. In the current paper, we investigate the cause behind the changes in the banks’ portfolio choice and its macroeconomic implication. We introduce the banks’ asset allocation decision into otherwise standard New Keynesian model. The banks construct their portfolio, taking the value at risk constraint into the consideration. While the government bond and the loan claim differ in terms of the expected average return, the banks choose their asset composition so that they do not default even when the maximum loss realize for the two assets. In the model, a tighter restriction on banks’ lending, a slower productivity growth rate, a deterioration of banks’ net worth, and an increase in expected maximum loss shift the banks’ asset from the lending to the government bond purchase, leading to a economic downturn and deflation.

Keywords: Value at Risk Constraint; Banks’ Asset Allocation; Deflation; Lost Decade.

1 Introduction

During the lost decades, the Japanese economy undergoes the long-lasting deflation and the unprecedented government debt. Focusing on that the banks’ asset allocation increasingly shift to the government bond holding from the lending to the firms during

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the period, we propose a theoretical explanation that stresses the implication of the banks' asset allocation to the macroeconomy.

To this end, we introduce the banks' portfolio allocation between the government bond holding and the loan claim to the firm into the otherwise standard New Keynesian model. The banks in the model choose the asset allocations, so that the value at risk constraint is not violated. Our model implies that a slow down of the total factor productivity growth rate, the disruption of the banks' net worth after the bubble burst, and an introducing of the capital requirement, encourage the banks to accumulate the government bond holding, reducing the loan claim to the firms. As the real capital investment is reduced, the output growth slows down, leading to deflation.

The current analysis is closely related to the work by Braun and Nakajima (2011). They study the impact of accumulated government debt on the price level, focusing on the banks' asset allocation. The banks in their model hold the government bond as the collateral to finance their asset purchase. So far as the they possess the optimistic view about the future bond price, they purchase the government bond by raising the fund from other agents, using the government bond as the collateral. Consequently, the accumulation of the government bond and the deflation coexist in the economy. While our paper also stresses the implication of the banks' asset allocation, the economic mechanism behind the banks' government bond holding differs from the one discussed in Braun and Nakajima (2011). In our paper, the key determinant of the banks' asset portfolio is the strength of the VaR constraint. Whenever the constraint is tightened, the banks tilt toward less risky assets from the risky assets.

One other research in line with our work is Brunnermeier and Sanikov (2011). They construct an economy where the market imperfection is present in the financial intermediation activity. Whenever the adverse shock hits the economy, the agents tilt their asset toward the safe asset, yielding deflation. This is because the safe asset is the nominal asset in their paper, and the tighter demand for the safe asset results in the decrease in the price level. Although the same mechanism is present in our model, the channel through which the banks’ asset allocation affect the inflation is different. In our model, the needs to the safer asset prevents the capital accumulation, dampening the output and generating the inflation.

In terms of the role played by the uncertainty, our analysis is also related to the work by Fernandez-Villaderde et al. (2011). They empirically find, using the structural vector autoregression, that a higher volatility in the productivity lowers the price level and the output, and provide a theoretical framework to analyze the relationship between the uncertainty and the households’ asset allocation. In their model based on the inventory model of money demand, they show that facing a larger uncertainty, the households prefer safer and more liquid asset, money, to riskier goods.

The rest of the paper is organized as follows. Section 2 presents our model where both the banks’ asset allocation is endogenized. We also explore the determinants of the asset returns and asset portfolio using a simplified setting. Section 3 demonstrates our
economy’s quantitative implications based on the model estimated using the Japanese data from 1980Q1 to 2007Q4. Section 4 concludes the analysis and discuss the future extension of our analysis.

2 The Model Economy

This section describes the structure of our model. The economy consists of six types of agents: households, banks, intermediate goods producers, final goods producers, government and central bank. See Figure 3 for model’s outline.

The households supply differentiated labor inputs to the intermediate goods producers and make deposit to the banks, receiving wage and repayment for the deposit in turn. They have no access to the financial market and the deposit is the only financial asset owned by the households. The banks collect the deposits from the households, allocating them to the two assets: the government bond and the loan claim to the capital goods used by the intermediate goods producers. The banks construct their asset portfolio composition so as not to violate the VaR constraint. The intermediate goods producers hire the labor supply and capital goods from the households and the banks, respectively, to produce the final goods. The final goods producers produce the differentiated final goods from the intermediate goods. They are monopolistic supplier of the final goods, and set their prices so as to maximize their profit. The government collects lump-sum tax from the households and issues the government bond to finance the government debt. The central bank controls the nominal interest rate according to a Taylor rule.

2.1 Household

Consider a continuum of households, indexed by \( h \in (0, 1) \). The infinitely-lived households make decision for consumption and deposit holdings. They are barred from the financial market, possess no real capital stock nor government bond, and hold all of her saving in the form of bank deposit.

A household \( h \) has preference over the consumption goods \( c(h, s^t) \), and work effort \( l(h, s^t) \), as described in the expected utility function, (1)

\[
E_0 \sum_{t=0}^{\infty} \beta^t \xi(s^t) U(c(h, s^t), l(h, s^t)) = E_0 \sum_{t=0}^{\infty} \beta^t \xi(s^t) \left( \log c(h, s^t) + \eta \log (1 - l(h, s^t)) \right),
\]

where \( \beta \in (0, 1) \) is the discount factor, \( \xi(s^t) \) is a shock to the discount factor, and \( \eta \) is the weighting assigned to leisure. \( c_t(h) \) is the composite of the differentiated final goods \( \{c(h, s^t, z)\} \) aggregated by the CES aggregator.
\[
c(h, s^t) \equiv \left[ \int_0^1 c(h, s^t, z)^{\frac{\epsilon(s^t)-1}{\epsilon(s^t)}} \frac{\epsilon(s^t)}{1-\epsilon(s^t)} \, dz \right]^{\frac{\epsilon(s^t)}{1-\epsilon(s^t)}} \quad \epsilon(s^t) > 1
\]
where and \( \epsilon(s^t) \in (1, \infty) \) denotes the time-varying elasticity of substitution between the differentiated final goods.

The budget constraint of the household is given by the equation below:

\[
c(h, s^t) + d(h, s^t) = r_d(s^t-1) d(h, s^{t-1}) + \frac{W(h, s^t)}{P(s^t)} l(h, s^t) + \Pi(h, s^t) - \tau(h, s^t) \tag{2}
\]
where \( d(h, s^t) \) is the household’s deposit, \( r_d(s^t-1) \) is the real deposit rate repaid by the banks for the deposit made in period \( t - 1 \), \( W(h, s^t) \) is the nominal wage rate, \( P(s^t) \) is the price index, \( \Pi(h, s^t) \) is the sum of the real profits of the intermediate goods producers and the banks that are returned to the household as dividends. \( \tau(s^t) \) is the lump-sum real tax collected by the government. We assume that the deposit is risk-free asset, and the real deposit rate is the real risk-free rate.

The first-order conditions associated with the household’s intertemporal decision is given by

\[
U_c(c(h, s^t), l(h, s^t)) = \beta r_d(s^t) E_t U_c(c(h, s^{t+1}), l(h, s^{t+1}))
\]
where \( U_c \) denotes the marginal utility with respect to the consumption. Because the household’s only financial asset is banks’ deposit, her consumption growth is dependent on the risk-free rate.

A household \( h \) is a monopolistic suppliers of differentiated labor service and sets her nominal wage rate in a staggered manner\(^1\). The differentiated labor supply \( l(h, s^t) \) is aggregated by the CES aggregator \( l(s^t) \), where

\[
l(s^t) = \left[ \int_0^1 l(h, s^t)^{\frac{\epsilon_l(s^t)-1}{\epsilon_l(s^t)}} \, dh \right]^{\frac{\epsilon_l(s^t)}{\epsilon_l(s^t)-1}}
\]
with an time-varying elasticity of substitution \( \epsilon_l(s^t) \in (1, \infty) \). The demand curve for differentiated labor service is given by

\[
l(h, s^t) = \left[ \frac{W(h, s^t)}{W(s^t)} \right]^{-\epsilon_l(s^t)} l(s^t),
\]
where \( W(s^t) \) denotes the aggregate wage index. Each period, the household can choose his nominal wages optimally by paying the adjustment cost à la Rotemberg (1982). The first order condition associated with labor supply decision gives

\(^1\)See, for instance, Fueki, Fukunaga, Ichiue, and Shirota (2010) for the details of the wage settings by the households that supply the differentiated labor input with the adjustment cost.
The outline of banks’ choice

2.2 Banks

There is a continuum of risk-neutral banks, indexed by \( i \in (0, 1) \). Each bank \( i \) collects deposit \( d(i, s^t) \) from the households, and purchases the capital stock \( b(i, s^t) \) and the real government bond \( b(i, s^t) \equiv \frac{B(i, s^t)}{P(s^t)} \), from the final goods producers and the government, respectively, using the deposit \( d(i, s^t) \) and its own real net worth \( n(i, s^t) \). The bank’s balance sheet each period is therefore given by

\[
k(i, s^t) + \frac{B(i, s^t)}{P(s^t)} = n(i, s^t) + d(i, s^t).
\]

The bank receives returns from the two assets invested in the previous period, repays the deposit to the households, and saves the rest of the earnings as the own net worth. Consequently, the bank’s net worth evolves according to the following law of motion:

\[
n(i, s^{t+1}) = r_k(s^{t+1}) k(i, s^t) + r_b(s^{t+1}) b(i, s^t) - r_d(s^t) d_t(i, s^t),
\]

where \( r_k(s^{t+1}) \) and \( r_b(s^{t+1}) \) are the real return to the capital stock holding and the government bond holding, respectively. Note that the real return to the government bond is given by the policy rate \( R_B(s^t) \) set by the central bank and the inflation rate \( \pi(s^{t+1}) \) through the relationship below.

\[
r_b(s^{t+1}) = \frac{R_B(s^t)}{\pi(s^{t+1})}.
\]

The bank keeps the net worth accumulation up to the period when it exits from the economy.\(^2\) We assume that the bank’s exiting probability each period is exogenously

\[\varepsilon_l(s^t) \frac{U_l(c(s^t), l(s^t))}{U_c(c(s^t), l(s^t))} = \begin{cases} \epsilon_l(s^t) - 1 & \frac{W(s^t)}{P(s^t)} \\ + \kappa_l \left( \frac{W(s^t)}{W(s^{t-1})} - \frac{W(s^{t-1})}{W(s^{t-2})} \right) \frac{W(s^t)}{W(s^{t})} \frac{W(s^t)}{P(s^t)} \right) \\ \beta \mathbb{E}_t \xi^t \left( \frac{W(s^{t+1})}{W(s^t)} - \frac{W(s^t)}{W(s^{t-1})} \right) \frac{W(s^{t+1})}{W(s^t)} \frac{W(s^{t+1})}{P(s^{t+1})} \frac{I(s^t)}{I(s^t)} \right) \end{cases},
\]

where \( U_l \) denotes the marginal utility with respect to the leisure and \( \kappa_l > 0 \) is a parameter that governs the nominal wage rigidity. We assume complete state-contingent markets and the identical initial conditions for all households so that we drop the household index \( h \) from variables hereafter.

\(^2\)Following Gertler and Karadi (2011), we assume that the bank transfers all of the accumulated net worth to the households when it exits from the economy.
given by \(1 - \gamma (s^t)\). The continuation value of the bank \(i\) is then given by

\[
V(n(i, s^t)) = \beta \mathbb{E}_t \xi(s^{t+1}) \Lambda_{t,t+1} \left[ \gamma(s^{t+1}) V(n(i, s^{t+1})) + (1 - \gamma(s^{t+1})) n(i, s^{t+1}) \right],
\]

where \(n(i, s^t)\) is the net worth held by the bank \(i\), and \(\Lambda_{t,t+1}\) denotes the households’ stochastic discount factor from the period \(t\) to the period \(t + 1\).

In choosing the asset portfolio composition between the two assets, the bank considers a value at risk constraint similar to the one discussed in Adrian and Shin (2011) as well as the expected average returns of the two assets. Namely, the bank constructs the asset portfolio in period \(t\) so that it is able to repay all of its debt to the household even if the two assets yield the lowest possible values. Denoting the worst return from holding the two assets by \(r_k(s^{t+1}|s^t)\) and \(r_b(s^{t+1}|s^t)\), respectively, the value at risk constraint is given by

\[
\ell_k(s^{t+1}|s^t) k(i, s^t) + \ell_b(s^{t+1}|s^t) b(i, s^t) - r_d(s^t) d(i, s^t) \geq 0.
\]

Here, we assume that the loan claim holding has a larger risk compared with the government bond holding, so that \(\ell_k(s^{t+1}|s^t) < \ell_b(s^{t+1}|s^t)^3\).

**The banks’ maximization problem**

The bank \(i\)’s optimization problem is formulated as the maximization of the value of the net worth at the last period shown by equation (5), subject to the bank’s balance sheet equation (3), the bank’s net worth accumulation (5), and the VaR constraint (3). Because the banks are risk-neutral, we first guess that the value function of the bank \(i\) is given by

\[
V(n(i, s^t)) = \phi(s^t) n(i, s^t),
\]

then the equation (5) is reduced to

\[
\max V(n(i, s^t)) = \beta \mathbb{E}_t \xi(s^t) \Lambda_{t,t+1} \left[ \gamma(s^t) \phi(s^{t+1}) \left( \frac{q_k(s^{t+1}) k(i, s^t)}{+q_b(s^{t+1}) b(i, s^t)} + \frac{r_d(s^t) d(i, s^t)}{+r_d(s^t) n(i, s^t)} \right) \right.

+ \left. (1 - \gamma(s^t)) \left( q_k(s^{t+1}) k(i, s^t) + q_b(s^{t+1}) b(i, s^t) + r_d(s^t) n(i, s^t) \right) \right].
\]

\(^3\)In the current paper, we concentrate our analysis on the equilibrium where the banks hold both of the two risky assets, and the worst returns of the two risky assets are smaller than the risk-free rate, so that the two equations below hold.

\[
\ell_k(s^{t+1}|s^t) - r_d(s^t) < 0,
\]

\[
\ell_b(s^{t+1}|s^t) - r_d(s^t) < 0.
\]
The corresponding first order condition gives

\[
E_t \left[ \frac{(\gamma \phi (s^{t+1}) + 1 - \gamma (s^t)) \Lambda_{t,t+1} q_k (s^{t+1})}{q_k (s^{t+1})} \right] = E_t \left[ \frac{(\gamma \phi (s^{t+1}) + 1 - \gamma (s^t)) \Lambda_{t,t+1} q_b (s^{t+1})}{q_b (s^{t+1})} \right].
\]

Here \( q_k (s^{t+1}) \equiv r_k (s^{t+1}) - r_d (s^t) \) and \( q_b (s^{t+1}) \equiv r_b (s^{t+1}) - r_d (s^t) \) denote the excess return to the loan claim holding and that to the government bond holding relative to the deposit, respectively. Similarly, \( q_k (s^{t+1}) \equiv r_k (s^{t+1}) - r_d (s^t) \) and \( q_b (s^{t+1}) \equiv r_b (s^{t+1}) - r_d (s^t) \) denote the excess return to the two risky assets when the worst return to the assets realize.

The equation (7) provides the fundamental principle that banks follow in allocating their assets into the loan claim and the government bond. Because the VaR constraint is effective, the excess returns are not equalized across the two assets. Instead, banks construct the portfolio so that the excess returns weighted by the worst excess returns are equalized across the two assets. When the holding of the loan claim is sufficiently riskier than that of the government bond, the average excess return needs to be higher for the loan claim is held by the banks.

From equations (6) and (7), we obtain the expression for \( \phi (s^t) \).

\[
\phi (s^t) = \beta E_t \left[ \Lambda_{t,t+1} \left\{ \gamma (s^t) \phi (s^{t+1}) + (1 - \gamma (s^t)) \right\} r_d (s^t) \left( 1 - q_k (s^{t+1}) / q_k (s^{t+1}) \right) \right].
\]

(8)

**Aggregation**

As the banks exit from the economy with probability \( 1 - \gamma (s^t) \) each period, the total bank’s net worth evolves according to the following law of motion;

\[
n (s^t) = \gamma (s^t) \left[ r_k (s^t) k (s^{t-1}) + r_b (s^t) b (s^{t-1}) - r_d (s^{t-1}) d (s^{t-1}) \right],
\]

where \( n (s^t) \) is the aggregate bank net worth. An increase in the exiting probability of the banks leads to a decline in the bank’s net worth in the subsequent period. As shown in the equation (6), a smaller net worth tightens the banks’ VaR constraint, affecting the banks’ asset allocation.4

### 2.3 Intermediate Goods Producers

The intermediate goods producers produce intermediate goods \( y (s^t) \) and sell them to the final goods producers with the price \( P_y (s^t) \). They hire labor inputs \( l (s^t) \) from the

4There are alternative ways to incorporate the shocks to the banks’ net worth into the model. In Gertler and Karadi (2011), the existing capital stock becomes out of date, deteriorating the value of the banks’ loan claim and net worth. In Aoki and Nikolov (2011) where the banks’ investment on the bubble is analyzed, the collapse of the bubble leads to a deterioration of the banks’ net worth.
household and borrow the effective capital \(v(s^t) K(s^{t-1})\) from the banks. Both the input market and the output market for the intermediate goods producers are competitive. The maximization problem of the intermediate goods producer is given by

\[
\max_{y(s^t), v(s^t) k(s^{t-1}), l(s^t)} \frac{P_y(s^t) y(s^t)}{P(s^t)} - \tilde{r}(s^t) v(s^t) k(s^{t-1}) - W(s^t) l(s^t),
\]

subject to

\[
y(s^t) = (v(s^t) k(s^{t-1}))^\alpha (A(s^t) l(s^t))^{1-\alpha},
\]

where \(v(s^t)\) is the capital utilization rate, \(k(s^{t-1})\) is the capital stock, \(\tilde{r}(s^t)\) is the real return to the use of effective capital, \(A(s^t)\) is the technology level, and \(\alpha \in [0, 1]\) is the capital share. The first order conditions of the intermediate goods producers yield the following equality.

\[
\tilde{r}_k(s^t) = \alpha \frac{P_y(s^t)}{P(s^t)} (v(s^t) k(s^{t-1}))^{\alpha-1} (A(s^t) l(s^t))^{1-\alpha},
\]

\[
W(s^t) = \frac{P_y(s^t)}{P(s^t)} (1-\alpha) (v(s^t) k(s^{t-1}))^\alpha (A(s^t))^{1-\alpha} (l(s^t))^{-\alpha}.
\]

The capital utilization rate is determined by the banks. Assuming that choosing capital utilization \(v(s^t)\), together with the capital stock \(k(s^{t-1})\), incurs the real cost of

\[
\frac{\kappa_v k(s^{t-1}) (v(s^t))^{\phi+1} - 1}{\phi + 1},
\]

to the banks, the optimal capital utilization rate for the banks is expressed as

\[
\tilde{r}_k(s^t) = (\phi + 1) \kappa_v v^{\phi}_t,
\]

where \(\kappa_v\) and \(\phi\) are parameters that govern capital utilization rate. Consequently, the banks’ net return to the investment on the capital stock is given by

\[
r_k(s^t) k(s^t) = \tilde{r}_k(s^t) k(s^t) - \kappa_v k(s^{t-1}) (v(s^t))^{\phi+1} + (1 - \delta) k(s^t),
\]

where \(\delta \in [0, 1]\) is the depreciation rate of the capital stock.

### 2.4 Final Goods Producers

We assume that final goods sector contains a continuum of firms, each producing differentiated products, as indexed by \(z \in [0, 1]\), from the final goods by the linear production technology

\[
x(z, s^t) = y(z, s^t).
\]
Here, \( x(z, s^t) \) is the product of the final goods producer \( z \) and \( y(z, s^t) \) is the intermediate goods used by the producer.

The demand for each of the differentiated final goods is given as a function of the price of its product \( p(z, s^t) \), the aggregate price index \( P(s^t) \), and the aggregate demand for the final goods \( x(s^t) \),

\[
   x(z, s^t) = \left( \frac{p(z, s^t)}{P(s^t)} \right)^{-\varepsilon(s^t)} x(s^t),
\]

and the firm \( z \) maximizes its profit by choosing the product price optimally. The final goods producer’s maximization problem is given by

\[
   \max_{p(z, s^{t+1})} \sum_{j=0}^{\infty} \beta^j \xi(s^t) \Lambda_{j-1,j} \left[ \left( \frac{p(z, s^{t+j})}{P(s^{t+j})} \right)^{1-\varepsilon(s^t)} x(s^{t+j}) - \left( \frac{p_y(s^{t+j})}{P(s^{t+j})} \right) \varepsilon(s^t) x(s^{t+j}) - \kappa \left( \frac{p(z, s^{t+j})}{p(z, s^{t+j-1})} \right)^2 \left( \frac{p(z, s^{t+j})}{P(s^{t+j})} \right)^{-\varepsilon(s^t)} x(s^{t+j}) \right].
\]

Note that the third term indicates that the firm has to pay an adjustment cost in changing its product price \( p(z, s^t) \), and \( \kappa \) is the parameter that governs the size of adjustment cost.

Considering that all of the differentiated goods prices set by the final goods producers are identical at the symmetric equilibrium, we obtain the Phillips curve of this economy from the first order condition of this problem.

\[
   - \varepsilon(s^t) \left( 1 - \frac{P_y(s^t)}{P(s^t)} - 0.5 \left( \pi(s^t) - 1 \right)^2 \right) + 1 - \kappa \left( \pi(s^t) - 1 \right) \pi(s^t)
   + \beta \kappa \left( \pi(s^{t+1}) - 1 \right) \pi(s^{t+1}) \frac{x(s^{t+1})}{x(s^t)} = 0. \tag{10}
\]

### 2.5 Government and Central Bank

The government collects a lump-sum tax \( P(s^t) \tau(s^t) \) from a household and newly issues a government bond \( B(s^t) \) to finance the repayment \( R_B(s^{t-1}) B(s^{t-1}) \) to the banks that held the government bond in the previous period. We assume that a balanced budget is maintained in each period \( t \) as:

\[
   R_B(s^{t-1}) B(s^{t-1}) = P(s^t) \tau(s^t) + B(s^t), \tag{11}
\]

where the left hand side denotes the repayment paid to the banks and the right hand side denotes the tax revenue. The government tax policy is an increasing function of the outstanding government bond as described by the following equation:
such that for all \(s^t\)

\[
\tau (s^t) = T \left( \frac{b(s^{t-1})}{x(s^t)} \right),
\]

where \(\psi \in (1, \infty]\) is an elasticity of lump-sum tax with respect to the government debt status, and \(T\) is a constant parameter.

The central bank sets the nominal interest rate according to a simple Taylor rule given by

\[
R_B (s^t) = R (\pi (s^t))^{\phi} \exp (\epsilon_r (s^t)),
\]

where \(\phi > 0\) is the policy weight attached to the inflation rate and \(\epsilon_r (s^t)\) is an i.i.d. shock to the monetary policy rule.

### 2.6 Shock Process

The exogenous shocks in our economy, the shock to the preference \(\xi (s^t)\), the two elasticities \(\varepsilon (s^t)\) and \(\varepsilon_i (s^t)\), the bank’s net worth \(\gamma (s^t)\), the two worst returns \(\tau_k (s^t)\) and \(\tau_b (s^t)\), and the technology level \(A (s^t)\) evolve following the equation below:

\[
\begin{align*}
\ln \xi (s^t) &= \rho_\xi \ln \xi (s^{t-1}) + \varepsilon (s^t), \\
\ln \varepsilon (s^t) &= (1 - \rho_\varepsilon) \ln \varepsilon + \rho_\varepsilon \ln \varepsilon (s^{t-1}) + \varepsilon (s^t), \\
\ln \varepsilon_i (s^t) &= (1 - \rho_{\varepsilon_i}) \ln \varepsilon_i + \rho_{\varepsilon_i} \ln \varepsilon_i (s^{t-1}) + \varepsilon_i (s^t), \\
\ln \gamma (s^t) &= (1 - \rho_\gamma) \ln \gamma + \rho_\gamma \ln \gamma (s^{t-1}) + \varepsilon_\gamma (s^t), \\
\ln \tau_k (s^t) &= (1 - \rho_{\tau_k}) \ln \tau_k + \rho_{\tau_k} \ln \tau_k (s^{t-1}) + \varepsilon_\tau (s^t), \\
\ln \tau_b (s^t) &= (1 - \rho_{\tau_b}) \ln \tau_b + \rho_{\tau_b} \ln \tau_b (s^{t-1}) + \varepsilon_\tau (s^t), \\
\ln A (s^t) &= \ln A (s^{t-1}) + u_A (s^t), \\
u_A (s^t) &= \rho_A u_A (s^{t-1}) + \varepsilon_A (s^t).
\end{align*}
\]

where \(\rho_\xi, \rho_\varepsilon, \rho_\varepsilon_i, \rho_\gamma, \rho_{\tau_k}, \rho_{\tau_b}, \rho_A \in (0, 1)\) are the autoregressive root of the corresponding shocks, and \(\varepsilon (s^t)\), \(\varepsilon_i (s^t)\), \(\varepsilon_\gamma (s^t)\), \(\varepsilon_\tau (s^t)\), \(\varepsilon_\tau (s^t)\), \(\varepsilon_\tau (s^t)\), \(\varepsilon_\tau (s^t)\), \(\varepsilon_\tau (s^t)\) are the exogenous i.i.d. shocks that are normally distributed with mean zero.

### 2.7 Equilibrium Condition

An equilibrium consists of a set of prices, \(\{W (s^t), P (s^t), P_y (s^t), r_k (s^t), r_d (s^t), r_b (s^t), R_B (s^t)\}_{t=0}^{\infty}\), and the allocations \(\{c (s^t), l (s^t), d (s^t), \Pi (s^t), k (s^t), v (s^t), x (s^t), y (s^t)\}_{t=0}^{\infty}\), for a given government policy \(\{G (s^t), \tau (s^t)\}_{t=0}^{\infty}\), realization of exogenous variables \(\{\varepsilon_\xi (s^t), \varepsilon (s^t), \varepsilon_i (s^t), \varepsilon_\gamma (s^t), \varepsilon_\tau (s^t), \varepsilon_\tau (s^t)\}_{t=0}^{\infty}\), the expected worst returns \(\{\tau_k (s^t), \tau_b (s^t)\}_{t=0}^{\infty}\), and initial conditions \(\{B_{-1}\}, \{d_{-1}\}, \{k_{-1}\}\) such that for all \(t, h, i, \) and \(z\) :
(i) the household \( h \) maximizes her utility given the prices;
(ii) the bank \( i \) maximizes its profits given the prices and the expected worst returns;
(iii) the intermediate goods producer \( z \) maximizes its profits given the prices;
(iv) the final goods producer \( z \) maximizes its profits given the prices;
(vi) the government budget constraint holds;
(vii) the central bank sets a policy rate following the Taylor rule; and
(viii) markets clear.

2.8 Steady State Analysis

Before investigating the model’s dynamics, we explore the model’s mechanism at the steady state to show the determinants of the banks’ portfolio composition. In particular, we focus on how the returns from holding the two risky assets \( r_b \) and \( r_k \) are affected by the banks’ VaR constraint, and how the banks’ decision as to the portfolio allocation between the government bond \( b \) and the loan claim \( k \) is made\(^5\). For illustrative purpose, we made two simplifying assumptions in this subsection: (1) the households supply labor inelastically, \( l = 1 \); and (2) the banks’ capital utilization cost is zero, \( \phi = 0 \)\(^6\).

Evaluating the portfolio choice equation, the VaR constraint equation, and the law of motion of the bank’s net worth at the steady state values, we have,

\[
\frac{r_k - r_d}{r_d - r_k} = \frac{r_b - r_d}{r_d - \gamma r_b}, \tag{22}
\]

\[
(r_k - r_d) k + (r_b - r_d) b = -r_d n, \tag{23}
\]

\[
n = \frac{\gamma}{1 - \gamma r_d} [(r_k - r_d) k + (r_b - r_d) b]. \tag{24}
\]

Notice that the household’s Euler equation at the steady state implies that

\[
r_d = \frac{1}{\beta}.
\]

The three equations above yield the excess return from holding the two risky assets, and the spread of the two risky assets;

\(^5\)The definition of the steady state in our economy needs to be carefully stated. Suppose that we define the steady state as the economy where all of the exogenous shocks are absent and every endogenous variables grow at the constant rate. The banks’ asset allocation then becomes indeterminate because the their portfolio choice is dependent on the riskiness of the assets. In the current paper, we define the steady state following the Devereux and Sutherland (2010, 2011) where the banks take the possibility that worst scenario of the asset return realize into the consideration. Consequently, the risks of holding the assets affect the banks’ portfolio at the steady state.

\(^6\)This assumption implies that the capacity utilization is unity.
\[ r_b - r_d = \frac{1 - \gamma r_d}{\gamma r_d} (r_d - r_b), \quad (25) \]
\[ r_k - r_d = \frac{1 - \gamma r_d}{\gamma r_d} (r_d - r_k). \quad (26) \]
\[ r_k - r_b = \frac{1 - \gamma r_d}{\gamma r_d} (r_b - r_k). \quad (27) \]

According to the equation (25) and (26), the excess return from holding the two risky assets and the spread between the two assets are expressed by the expected worst returns from holding the two risky assets \( r_b \) and \( r_k \), together with the bank’s survival probability \( \gamma \).

When the risk of holding the loan claim \( r_k \) increases, for instance, the bank’s VaR constraint becomes tightened unless the bank reduces the loan claim. Consequently, the bank requires a higher spread in holding the loan claim than otherwise. The government bond yield is unaffected by the change in \( r_k \). The similar mechanism works if the risk of holding the government bond \( r_b \) increases.

By contrast, a reduction in the survival probability \( \gamma \) lead to a rise in the two excess returns. As indicated by the equation (24), the smaller probability prevents the banks from accumulating the net worth. Because the scarcity of the net worth tightens the bank’s balance sheet, it results in the reduction of the bank’s purchase of both of the two risky assets. The excess returns for the two assets therefore increase to clear the demand.

Next, we discuss how the banks allocate their asset between the loan claim \( k \) and the government bond \( b \). Because the return from holding the loan claim \( r_k \) equals to the return to the capital stock in the economy, we have

\[ r_k = \alpha Ak^{\alpha - 1} + (1 - \delta). \]

Since the loan claim is equivalent to the capital stock in the equilibrium, we have

\[ k = \left[ \frac{r_k - (1 - \delta)}{\alpha A} \right]^{\frac{1}{\alpha-1}}. \quad (28) \]

Taking that \( \alpha - 1 < 0 \) into the consideration, a higher return for the loan claim implies a smaller size of a loan claim and thus a smaller investment in the economy. Based on the discussions above, an increase in the risk of holding the loan claim or a decline in the banks’ surviving probability reduce the loan claim through a rise in the return \( r_k \).

The bank’s decision as to the holding of the government bond is affected by the government policy regarding taxing and budget balance. From the equations (11) and (12), we have
Here we assume that inflation rate is unity as the steady state. These governmental equations suggest, for a value $\psi > 1$, that the banks tilt toward holding of the government bond as the corresponding return increases. Under the current tax policy, an increase in the government’s interest rate payment is met by the comparable increase in government bond issuance, leading to a higher government bond holding by banks. Similarly to the working mechanism that determinants the loan claim $k$, the increasing risk of holding the government bond, given by a decline in $r_b$, or the disruption of the bank’s net worth, given by a decline in $\gamma$, leads to an increase in the bank’s government bond holding, through a rise in the government bond yield.

Lastly, we discuss how the bank allocates its asset between the government bond holding and the loan claim to the firms. From the equations (28) and (29), the government bond holding relative to the loan claim is given by

$$\frac{b}{k} = \left[ \frac{r_b - 1}{T} \right]^{\psi} \left[ \frac{r_k - (1 - \delta)}{\alpha} \right].$$

According to the above equation, any changes in the economic environments that boost the return to the two risky assets $r_b$ and $r_k$, including the increasing risk of lending to the firms, that of holding the government bond, or the disruption of the bank’s net worth, cause the bank to purchase more of the government bond compared with the loan claim to the firms.

To summarize, the key determinants behind the banks’ tilting toward the government bond are the relative increase in the risk of holding the real asset and the shortage of the banks’ net worth. In the next subsection, we depart from the steady state analysis, and explore the implication of the bank’s asset allocation to the inflation dynamics, by log-linearizing our model around the steady state.

2.9 VaR Constraint and Inflation Dynamics

By log-linearizing equations (7) and (13) around the steady state, we have

$$\frac{r_b b}{r_k - r_d} \hat{r}_d (s^{t+1}) + E_t \left( \frac{E_k}{r_d - \hat{L}_k} \hat{r}_k (s^{t+1}) \right) - E_t \left( \frac{r_b}{r_d - \hat{L}_b} \hat{r}_b (s^{t+1}) \right) - E_t \left( \frac{E_b}{r_d - \hat{L}_b} \hat{r}_b (s^{t+1}) \right)$$

$$= \left( \frac{r_d}{r_k - r_d} - \frac{r_d}{r_b - r_d} + \frac{r_d}{r_d - \hat{L}_k} - \frac{r_d}{r_d - \hat{L}_b} \right) \hat{r}_d (s^t).$$
\[ \hat{R}_b (s^t) = \phi \hat{\pi} (s^t). \]  

Here \( \hat{\lambda}(s^t) \) denotes the log deviation of a variable \( \lambda(s^t) \) from its steady state value. Taking the following relationship

\[ \hat{r}_b (s^{t+1}) = \hat{R}_{b,t} - \hat{\pi} (s^{t+1}) \]

into our consideration, we have

\[ \hat{\pi} (s^t) = \phi^{-1} E_t \left[ \hat{\pi} (s^{t+1}) + a_1 \hat{r}_k (s^{t+1}) + a_2 \hat{r}_{k} (s^{t+1}) - a_3 \hat{r}_b (s^{t+1}) + a_4 \hat{r}_d (s^t) \right]. \]  

Here, \( a_1, a_2, a_3, \) and \( a_4 \) are all positive values that are denoted by

\[
\begin{align*}
a_1 &= \frac{r_b - r_d}{r_k - r_d}, \\
a_2 &= \frac{r_b - r_d}{r_k - r_d}, \\
a_3 &= \frac{r_b - r_d}{r_k - r_d}, \\
a_4 &= \frac{r_b - r_d}{r_k - r_d} \left[ \left( \frac{r_d}{r_k} - \frac{r_d}{r_b} \right) + \left( \frac{r_d}{r_k - r_d} - \frac{r_d}{r_k} \right) \right].
\end{align*}
\]

The equation (32) indicates the qualitative link between the banks’ asset allocation and inflation rate in the economy. Other things, including the inflation expectation \( E_t [\hat{\pi} (s^{t+1})] \), being equal, inflation is determined by the four variables, \( \hat{r}_k (s^{t+1}) \), \( \hat{r}_k (s^{t+1}) \), \( \hat{r}_b (s^{t+1}) \), and \( \hat{r}_d (s^t) \). Suppose the return from holding the loan claim is high, an ample capital is accumulated, yielding a strength to the economy and generating inflation. The decrease in the risk of holding the loan claim \( \hat{r}_k (s^{t+1}) \) or the increase in the risk of holding the government bond \( \hat{r}_b (s^{t+1}) \) causes the inflation through the similar mechanism. The rise in the deposit rate \( \hat{r}_d (s^t) \) generates inflationary pressures to the economy. While a higher deposit rate prevents the net worth accumulation of the banks, it encourages the banks’ purchase of the loan claim relative to the government bond, increasing the capital goods in the economy. The mechanism behind is that under the premise that

\[ r_k < r_b < r_d < r_b < r_k, \]

the excess return to the government bond is sensitive to a change in the deposit rate compared with that to the loan claim. Consequently, the banks’ asset allocation tilt towards the real capital, leading to inflation in the economy.

3 Quantitative Analysis

In this section, we investigate the quantitative implication of our model, including the role played by the banks’ VaR constraint. Based on the Japanese data, we first estimate
the model’s parameters and extract the eight structural shocks, $\epsilon_\xi (s^t)$, $\epsilon_\varepsilon (s^t)$, $\epsilon_{\varepsilon_1} (s^t)$, $\epsilon_{\varepsilon_2} (s^t)$, $\epsilon_{\varepsilon_3} (s^t)$, $\epsilon_{\varepsilon_4} (s^t)$, $\epsilon_{\varepsilon_5} (s^t)$ and $\epsilon_{\varepsilon_6} (s^t)$, using the Bayesian technique. We then explore the model’s equilibrium response to these exogenous shocks. In particular, we discuss how the VaR constraint affects the model’s dynamics after the shocks. Next, we explore the quantitative contribution of each shock in explaining the variations of macroeconomic variables, including the banks’ asset allocation, inflation, and GDP.

### 3.1 Data

Our benchmark dataset includes eight time series for the Japanese economy from 1980Q1 to 2007Q4: namely, (1) the labor input\(^7\), (2) the real private investment based on National Accounts of Japan, (3) the government bond held by the banks based on Flow of Funds, (4) the net worth of the banks based on Flow of Funds, (5) the capacity utilization of manufacturing industry based on the indices of industrial production, (6) the quarterly difference of the GDP deflator based on National Accounts of Japan, (7) the call rate set by the Bank of Japan, and (8) the real GDP based on National Accounts of Japan. The series (3) and (4) are converted into the quantity, using the GDP deflator. All the series, other than the series (5), (6), and (7), are detrended by the linear trends.

### 3.2 Prior and Posterior Distribution of the Parameters

The parameter values used for our quantitative analysis are reported in Table 1. The parameter values are quarterly unless otherwise noted. Since our model is a standard New Keynesian model except that our model incorporates the banks’ asset portfolio choice, we set some of the parameters to the conventional values. These parameters are reported in Table 1(2).

Other parameters are estimated by the Bayesian technique. The third to the fifth columns of Table 1(1) report the prior distribution of the estimated parameters. The last three columns in Table 1(1) display the posterior mean and the confidence intervals of the model parameters.

### 3.3 Impulse Responses

In this subsection, we investigate the economy’s dynamic response to a structural shocks. Figure 4, 5, 6, and 7 display the economy’s impulse response function to a shock to the technology growth rate $\epsilon_\lambda (s^t)$, the banks’ net worth shock $\epsilon_\gamma (s^t)$, the maximum loss to the holding of loan claim $\epsilon_\delta (s^t)$, and the maximum loss to the holding of government bond $\epsilon_\delta_b (s^t)$.

\(^7\)To construct the labor input series, we follow the methodology adopted in Hayashi and Prescott (2002).
Figure 4 displays the economy’s response to a negative shock to a technology growth rate that brings about a permanent level down of the technology to the economy. To illustrate the quantitative role played by the VaR constraint, we construct an alternative model that is absent from the VaR constraint. In this economy, because the equation (6) is not binding, the returns from holding the loan claim and that from holding the government bond become equivalent to the deposit rate. In the figure, the estimated model’s impulse is denoted by the line with white circles, and the impulse under the economy without the VaR constraint is denoted by the line with black circles. Other things being equal, the slow down of the technology growth rate reduces the output, generating the deflationary pressure to the economy. In addition, since the return from holding the loan claim is reduced, the banks tilt their asset portfolio towards the government, reducing the output further. Consequently, output decline and deflation are pronounced under the economy with VaR constraint.

Figure 5 displays the consequence of the banks’ net worth disruption caused by the decrease in the banks’ surviving probability. We do not plot the equilibrium response in the economy where the VaR constraint is absent, since the variations in the banks’ net worth cannot be a source of the economic fluctuations in such an economy. There are two channels through which the smaller banks’ net worth affects the banks’ asset allocation. First, the banks shrink their balance sheet, reducing the purchase of both the government bond and the loan claim. With their net worth deteriorated, other things being equal, the banks find it difficult to repay their debt in the case that the maximum loss realize. The banks thus reshuffle their asset portfolio so as to meet the VaR constraint. Second, the banks reduce the purchase of the loan claim disproportionately. This is because the banks tilt their assets toward safer asset as the VaR constraint is tightened. The both channels lead to a reduction in the aggregate investment on the real capital, dampen the output and suppress the inflation.

Figure 6 displays the equilibrium response to the increase in the maximum loss in holding the loan claim. This shock is interpreted as an unexpected increase in the downside risk associated with the capital investment or as an unexpected tightening of the capital requirement introduced by the governmental initiatives. As indicated by the equation (7), the banks tilt the asset portfolio toward the asset whose average expected return weighted by the maximum loss is higher. Consequently, the banks reduce the loan claim and increase the government bond purchase. The reduced loan claim implies a reduced capital, leading to a depressionary pressure to the economy.

Figure 7 displays the equilibrium response to the increase in the maximum loss in holding the government bond. Similarly to the case of loan claim, this shock is also interpreted as an unexpected increase in the downside risk associated with the government bond holding or as an unexpected tightening of the capital requirement introduced by the governmental initiatives. In this case, the banks reduce the government bond purchase, increasing the capital goods purchase, following the equation (7), resulting in the output expansion and inflation.
3.4 Historical Decomposition

Using the estimated model parameters and extracted shocks, we investigate the role of each structural shock in explaining macroeconomic variations during the lost decades. Figure 8 displays the historical decomposition of GDP, inflation, and government bond purchase from 1980Q1 to 2007Q4 into the eight shocks. Table 2 reports the average contribution of each shock in explaining these three variables.

In explaining GDP variations, in particular during the period after the bank crisis that took place in the latter half of 1990s, the shocks to technology growth rate and the maximum loss of holding the loan claim fasten the GDP growth, while shocks to the markup regarding the final goods price and the households’ nominal wage slower the GDP growth. The shocks to the banks’ net worth work as a main source behind the output slow down, and their effects are persistently lowering the output growth up to now. The net worth shocks tighten the banks’ VaR constraint and reduces the capital investment, dampening the output. On average, the markup shocks, the net worth shocks, and the technology shocks explain 48%, 22%, and 17% of the output variations.

As for the inflation variations, the shocks to the markup helps raising the inflation particularly after the first half of the 1990s, and the shocks to the productivity growth, the banks’ net worth, and the maximum loss of the loan claim help lower the inflation. As we see in the exercise about the impulse response function, the technology slow down, the deterioration of the banks’ net worth, and the increase in the maximum loss of ght governmeenb bond, tightens the lending to the firms, through a shift in the banks’ asset portfolio from the loan claim to the government bond. As the economic activities is weakened, the deflation pressure becomes prominent. Quantitatively, the markup shocks, the net worth shocks, and technology shocks explain 66%, 14%, and 9% of the inflation variations.

As for the variations of the government bond purchase, the shocks to the markup contribute positively particularly after the first half of the 1990s, and the shocks to the productivity growth, the banks’ net worth, and the maximum loss of the loan claim contribute negatively. As we see in the exercise about the impulse response function, the technology slow down, the deterioration of the banks’ net worth, and the increase in the maximum loss of ght governmeenb bond, tightens the lending to the firms, through a shift in the banks’ asset portfolio from the loan claim to the government bond. As the economic activities is weakened, the deflation pressure becomes prominent. Quantitatively, the markup shocks, the net worth shocks, and the technology shocks explain 66%, 14%, and 9% of the variations of the government bond purchase.

4 Conclusion

During the lost decades, the Japanese economy undergoes the long-lasting deflation and the unprecedented government debt. Focusing on that the banks’ asset allocation
increasingly shift to the government bond holding from the lending to the firms during the period, we propose a theoretical explanation that stresses the implication of the banks’ asset allocation to the macroeconomy.

To this end, we introduce the banks’ portfolio allocation between the government bond holding and the loan claim to the firm into the otherwise standard New Keynesian model. The banks in the model choose the asset allocations, so that the value at risk constraint is not violated. Our model implies that a slow down of the total factor productivity growth rate, the disruption of the banks’ net worth after the bubble burst, and an introducing of the capital requirement, encourage the banks to accumulate the government bond holding, reducing the loan claim to the firms. As the real capital investment is reduced, the output growth slows down, leading to deflation.

Our results have policy implications when the economic recession is associated with the banks’ risk taking behaviors. In the economy where the uncertainty about capital investment plays as the key obstacle in reducing the investment, the policy aiming to reduce the minimum loss of investment may be effective.
References


Accumulation of Government Debt and Deflation

(1) Government Debt over GDP

(2) Money Stock over GDP

(3) Inflation Dynamics

Banks' Asset Allocation

1. Public Bond held by Japanese Banks

2. Portion of Public Bond in the Banks' Asset

3. Portion of Loan Claim in the Banks' Asset

Banks

- Invest on Loan Claim to Firms and Government Bond Purchase, using Deposit and Own Net worth
- Construct Asset Portfolio, considering the Value at Risk Constraint

Goods Producers

- Produce Goods from Labor and Capital

Households

- Make a Deposit to Banks

Government

- Tax Households to finance repayment.
- Central Bank adjusts Policy Rate, following Taylor Rule.
Model's Response to a shock to Technology Growth

(1) Output

(2) Inflation

(3) Investment (Loan + Government Bond)

(4) Spread of Loan Claim

(5) Bond/Claim Ratio

(6) Banks' Net Worth

(note) Vertical axis denotes the deviation from the steady state and horizontal axis denotes the number of quarter after the shock.
Model's Response to a shock to Banks' Net Worth

Vertical axis denotes the deviation from the steady state and horizontal axis denotes the number of quarter after the shock.
Model's Response to a shock to Maximum loss of Loan Claim

1. Output
2. Inflation
3. Investment (Loan + Government Bond)
4. Spread of Loan Claim
5. Bond/Claim Ratio
6. Banks' Net Worth

(note) Vertical axis denotes the deviation from the steady state and horizontal axis denotes the number of quarter after the shock.
Model's Response to a shock to Maximum loss of Government Bond Holding

(Note) Vertical axis denotes the deviation from the steady state and horizontal axis denotes the number of quarter after the shock.
Decomposition of Macroeconomic Variables

(1) Output

(2) Inflation
Decomposition of Macroeconomic Variables

(3) Purchase of Government Bond

(Figure 8)
## Parameter of Model

### (1) Estimated Parameters

<table>
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<th>Parameter</th>
<th>Prior Dist.</th>
<th>Prior Mean</th>
<th>Prior Std.</th>
<th>Posterior mean</th>
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<tr>
<td>$\sigma_{D}$ Shock to Demand SD</td>
<td>invg</td>
<td>0.01</td>
<td>10</td>
<td>0.002</td>
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</table>

### (2) Calibrated Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>$\alpha$ Capital Share in Final Goods Production</td>
<td>0.35</td>
</tr>
<tr>
<td>$\beta$ Households' Discount Factor</td>
<td>0.99</td>
</tr>
<tr>
<td>$\eta$ Households' Preference over Leisure</td>
<td>0.5</td>
</tr>
<tr>
<td>$\delta$ Depreciation Rate</td>
<td>0.025</td>
</tr>
</tbody>
</table>
### Contribution of Structural Shocks

#### (1) Output (Detrended, Growth Rate)

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Banks' net worth</td>
<td>16.3</td>
<td>15.2</td>
<td>22.2</td>
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<tr>
<td>Households' demand</td>
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<td>1.2</td>
<td>0.9</td>
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<tr>
<td>Maximum loss to loan claim</td>
<td>3.5</td>
<td>7.8</td>
<td>6.6</td>
</tr>
<tr>
<td>Maximum loss to government bond</td>
<td>0.5</td>
<td>1.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Monetary Policy</td>
<td>9.9</td>
<td>0.4</td>
<td>5.1</td>
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<tr>
<td>Markups</td>
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<td>62.6</td>
<td>47.7</td>
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<tr>
<td>Technology growth</td>
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<td>11.3</td>
<td>16.7</td>
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#### (2) Inflation (Growth Rate)

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<tbody>
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<td>0.3</td>
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<td>Maximum loss to loan claim</td>
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<td>4.1</td>
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<tr>
<td>Maximum loss to government bond</td>
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<td>7.5</td>
<td>4.1</td>
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<tr>
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<td>58.5</td>
<td>66.1</td>
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<tr>
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<td>8.0</td>
<td>7.5</td>
<td>8.9</td>
</tr>
</tbody>
</table>

#### (3) Government bond purchase

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>Banks' net worth</td>
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<td>6.3</td>
<td>4.3</td>
</tr>
<tr>
<td>Households' demand</td>
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<td>0.1</td>
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<td>Maximum loss to loan claim</td>
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<td>Maximum loss to government bond</td>
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<tr>
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<tr>
<td>Technology growth</td>
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