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"Search-for-Yield and Business Cycle*"

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Search-for-Yield and Business Cycle *

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Abstract

Observing ultra-low interest yields in recent years, it is often pointed out that the existence of "search-for-yield" behaviors of financial institutions might have been intensifying interest rate drops. One hypothesis to explain "search-for-yield" is that banks try to buy longer-term bonds even when they expect upward paths of the short-term interest rate and they recognize negative term premium in long-term rates because they care about current portfolio income, not just expected holding-period returns. A main purpose of this paper is to study implications about general equilibrium effects from the existence of banks with this type of "search-for-yield". Hanson and Stein (2015) give explanations about what these investors bring to the long-term interest rate pricing from their partial equilibrium model. I incorporate a similar setting to theirs into a general equilibrium model with banks exposed to the value at risk constraint. Implications found here are as follows. First, the existence of these banks makes recovery path after negative productivity shock hits the economy more sluggish. Second, as Hanson and Stein (2015) suggest, we observe lower term premium in the long-term bond interest rate. Third, when the fiscal authority is more sensitive to the increase in bond outstanding, these impacts become smaller.

JEL classification: E32, E43, G11, G12

Keywords: Business cycle, Irrationality, Yield-search, Long-term real rates, Value at Risk Constraint, Banks' asset allocation

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1 Introduction

In recent years, ultra-low yields have been widely observed in global bond markets. Both academia and participants in the financial industry have intensively commented that we have been observing "search-for-yield" or "reaching-for-yield" behaviors of financial investors especially since major central banks in developed countries conducted unconventional monetary easing policies.

It is referred to as "search-for-yield" that financial institutions shift their fixed-income portfolio into riskier assets with higher yields as interest rates decline. It would be convenient to have three layers to categorize research on "search-for-yield" occurrences in literature. First, types of risks financial institutions take. They are largely divided into two, credit risks and duration risks. Second, types of reasoning about why investors conduct "search-for-yield". These could be classified to institutional constraints including accounting considerations, regulatory constraints, and incentive problems without institutional or regulatory constraints. Third, types of financial investors discussed include banks, investment funds, and life insurance companies[1].

Among these varieties, one hypothesis to explain "search-for-yield" is that banks buy longer-term bonds caring about current portfolio income or yield, not just expected holding-period returns, even when they expect upward paths of the short-term interest rate and they recognize negative term premium in long-term rates. This could be because of agency or accounting considerations that lead them to worry about short-term measures of reported performance[2].

From this angle, Hanson and Stein (2015) argue that demand effects due to the existence of "yield-oriented investors" who conduct "search-for-yield" in this sense could generate negative term premium of long-term rates while the standard C-CAPM theory has difficulties to explain time variation of term premium. Figure 1 shows 10 year US treasury term premium estimated by Adrian et al. (2013), along with 10 year treasury rate. The figure indicates that term premium has been negative in recent years.

[1]For example, Rajan (2006) discusses incentive issues of financial institutions including banks, investment fund managers, and life insurance companies. Jimenez et al. (2014) explore an idea that banks take on more credit risk when rates are low. Hanson and Stein (2015) argue this issue in the context of duration risks taken by investors including commercial banks because of agency or accounting considerations that lead them to worry about short-term measures of reported performance. Memmel et al. (2016) investigate banks exposure to interest rate risk from the point view of the level of profits. Domanski et al. (2015) argue about duration lengthening by long-term investors such as life insurance companies and pension funds under declining long-term interest rates.

[2]See Hanson and Stein (2015).

The purpose of this paper is to investigate how "search-for-yield" by banks which take duration risks by near-term accounting considerations impacts the general equilibrium of the economy. In order to purse this, we develop a model that incorporates two types of banks, rational and irrational, and demand for long-term government bonds from them into an otherwise standard RBC model. Rational banks we call "expected return-oriented banks" (hereafter, EO banks) rationally expect the deposit rate path in bond pricing while irrational banks we call "yield-oriented banks" (hereafter, YO banks) expect that the deposit rate will stay flat over the maturity of long-term government bonds. Hanson and Stein (2015) set the expectation formation by YO banks in this way to depict "search-for-yield" from near-term income considerations in their partial equilibrium model of the bond market[3].

General equilibrium structures with banks in this paper follow a model of Aoki and Sudo (2013) which includes banks' portfolio choices between capital and government bonds. In their model, banks collect deposits from the households, and invest them and their own net worth into these assets. They decide their balance sheet sizes and asset portfolio allocations so as to satisfy the value-at-risk constraint (hereafter, VaR constraint). In our model, differently from Aoki and Sudo (2013), banks have long-term bonds in their portfolio, instead of short-term bonds. Also, we have two types of banks with rational and irrational bond pricing motivated by Hanson and Stein (2015) as noted above. Hanson and Stein (2015) describe a partial equilibrium model of the bond market with exogenously given supply and heterogeneous demand. In our model, the bond supply is endogenized by the government budget constraint while the bond demand structure follows Hanson and Stein (2015). Having these settings allows us to investigate general equilibrium effects from irrational expectation formations.

Major implications found here are as follows. First, recovery processes after the negative shock hits the economy become more sluggish. The existence of yield-oriented banks which irrationally price long-term bonds makes ex-post returns to banks' net worth lower. This consequently changes investment decisions about production capital holdings because they try to maintain their solvency under the worst case caputal return scenario by reducing the

[3] Hanson and Stein assume that there are two types of investors, "expected return-oriented investors" who maximize expected holding-period returns, and "yield-oriented investors" who maximize current income. Both investors purchase long-term bonds (two-period bonds) and finance this position by rolling-over short-term (one-period) borrowing under mean-variance optimizations with second period short-term rate uncertainty. In order to formulate an optimization problem in which yield-oriented investors maximize current income, they assume that these investors expect short-term rates are flat over two-periods. The sum of bond demand from two types of investors and fixed supply of long-term bonds are able to generate negative term premium which depends on the share of yield-oriented investors and a path of short-term bond rates expected by expected return-oriented investors.

balance sheet sizes and adjusting portfolio choices. Second, we observe lower term premium in long-term bonds than in a case where only rational banks exist. Third, the fiscal policy side has non-negligible effects. Under an economy in which the fiscal authority is more sensitive to increase in bond outstanding, output and term premium differences between two types of economies with and without YO banks become smaller.

It is important to note that our model is a real one and that the analysis of central banks' operations to adjust the market supply of government bonds is outside of the scope to simplify discussions.

The rest of the paper is organized as follows. Section 2 presents our model. Section 3 discusses quantitative results based on the model. Section 4 conducts some experiments to understand what characteristics close gaps between an economy with EO banks and that with YO banks. Section 5 concludes the analysis and discusses the future extension of our analysis.

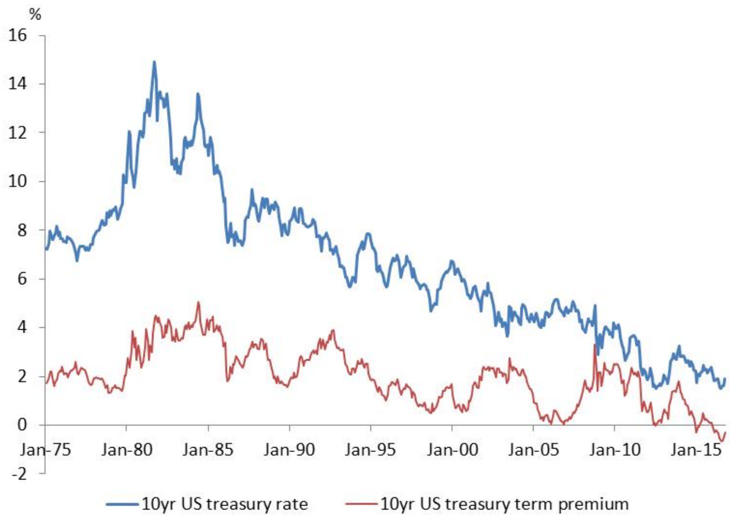

Figure 1: 10 year US treasury term premium

Source: Federal Reserve Bank of New York. This figure presents "ACM" term premium by Adrian. et al.(2013)

2 Model

The economy that we model consists of a representative household, banks, firms (goods producers), capital producers, and the government. I assume two types of banks. "Expected return-oriented (EO) bank" and "yield-oriented (YO) bank". The former rationally forms the expectation about deposit rates which are funding costs for them. The latter expects that deposit rates will take flat paths over long-term government bond maturity at each time of bond purchasing. We assume this formulation of expected deposit rate paths by YO banks in order to describe their caring about current income. Both banks collect deposits from the household, and invest their own net worth and deposits in two types of assets, capital stock, and long-term government bonds.

The representative household supplies labor to goods producers, receives wages, makes deposits at the banks. The household does not have access to the financial market other than deposits. Banks choose asset allocations so that they do not violate the VaR constraint. Goods producers hire labor and borrow capital goods from banks in competitive markets. Capital producers sell capital goods to banks. The government collects tax from the household in a lump-sum way and issues long-term (two-period) government bonds to finance government debts and government expenditures.

2.1 Banks

At time t, banks collect deposits D_t from the household and purchases capital stock K_t and long-term government bond B_t. They finance purchases of assets by the deposit and net worth N_t. The government issues the two-period bond. B_t provides the same real returns, $R_{B,t+1}$ over two periods after purchases, $t+1$ and $t+2$. I assume that there is no secondary market for the bond. Therefore, banks continue to hold them up to their maturities. Superscripts, e and y, used in this paper indicate variables of expected return-oriented (EO) banks and yield-oriented (YO) banks, respectively.

2.1.1 Expected return-oriented (EO) banks

EO banks' balance sheet at time t is given by

$$K_t^e + B_{t-1}^e + B_t^e = D_t^e + N_t^e. \tag{1}$$

I assume that N_t^e is a state variable which is pre-determined at the beginning of time t.[4]

Banks receive returns from the two types of assets they invested in the previous period, repay deposits to the household, and accumulate their own net worth. Therefore, banks' net worth evolves according to the following law of motion,

$$\begin{aligned} N_{t+1}^e =& R_{K,t+1}K_t^e + R_{B,t}B_{t-1}^e + R_{B,t+1}B_t^e \\ &- \frac{1}{2}\chi B_t^{e^2} - R_{D,t+1}D_t^e. \end{aligned} \tag{2}$$

$R_{K,t+1}$ and $R_{B,t+1}$ are real gross returns on capital and government bond between time t and $t+1$, respectively. $R_{D,t+1}$ is the deposit rate between time t and $t+1$, which is risk-free.[5] Because the government bond is a two-period bond, banks receive same real returns over two periods after they purchase them. We assume banks need to pay long-term bond holding costs, $\frac{1}{2}\chi B_t^{e2}$, where χ is a constant.[6]

Banks choose their portfolio size and allocation between the two types of assets subject to the VaR constraint. This setting is similar to what is used in Aoki and Sudo (2013). Banks

[4] For clarification, time notations in Dynare codes for EO banks' balance sheet (1) and net worth law of motion (2) are shown in the appendix.

[5] Here, risk-free means that the rate is known at period t. In the VaR constraint (3), it is possible that banks cannot repay all of their deposit without any transfer from the household if realized bond return and capital return as well are extremely lower than they expected. However, our model is constructed so that banks receive positive transfer for them from the household and repay deposit costs in that case.

[6] This quadratic representation of bond holding costs is a device to generate bond supply effects on its return under the first-order approximation.

adjust their balance sheet in period t, so that they are able to repay all of their debts to the household even if the capital return becomes the worst scenario which they assume to occur in their in period $t+1$. The assumed worst case return from capital holdings is $\underline{R_K}$ which is exogenously given.[7] The VaR constraint is given by

$$\underline{R_K} K_t^e + R_{B,t} B_{t-1}^e + R_{B,t+1} B_t^e - \frac{1}{2}\chi B_t^{e2} - R_{D,t+1} D_t^e \geq 0. \tag{3}$$

Eliminating D_t^e, we get

$$\begin{aligned} N_{t+1}^e =& (R_{K,t+1} - R_{D,t+1}) K_t^e + (R_{B,t} - R_{D,t+1}) B_{t-1}^e + (R_{B,t+1} - R_{D,t+1}) B_t^e \\ & - \frac{1}{2}\chi B_t^{e2} + R_{D,t+1} N_t^e \end{aligned} \tag{4}$$

and

$$\begin{aligned} & (\underline{R_K} - R_{D,t+1}) K_t^e + (R_{B,t} - R_{D,t+1}) B_{t-1}^e + (R_{B,t+1} - R_{D,t+1}) B_t^e \\ & - \frac{1}{2}\chi B_t^{e^2} + R_{D,t+1} N_t^e \geq 0. \end{aligned} \tag{5}$$

Next, I formulate a banks' maximization problem. Following Gertler and Karadi (2011) and others, I assume that banks maximize the discounted stream of payout to the household. Therefore, the discount rate Λ is set to be the household's intertemporal marginal rate of substitution. Under financial market frictions, it is optimal for the bank to retain net worth until exiting which occurs by probability $1-\theta$. By this reasoning, the bank's objective is to maximize expected terminal wealth V_t at time t, given by,

$$V_t^e = \max_{\{B_{t+i}^e\}_{i=0}^{\infty}} E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i+1} \theta^i N_{t+i+1}^e \tag{6}$$

subject to the net worth evolution (4) and the VaR constraint (5). The discount rate Λ is defined as

$$\Lambda_{t,t+i+1} = \beta^{i+1} \frac{U_c(C_{t+i+1}, L_{t+i+1})}{U_c(C_t, L_t)}, \tag{7}$$

where $U_c(C_t, L_t)$ is the first-order derivative of the household utility with respect to C_t which

[7] A difference from Aoki and Sudo (2013) is that in our model we assume that banks set the worst case return on capital in the VaR constraint by their business judgements while Aoki and Sudo (2013) consider the VaR constraint with both of the worst case returns from capital and bonds so that banks do not go bankrupt under any realized returns even without any transfer from the household.

specific representation is defined later.

As noted earlier, banks need to pay long-term bond holding costs given by $\frac{1}{2}\chi B_t^{e2}$, which is not a linear function. Therefore, we cannot necessarily guess V_t^e as a linear function of B^e, K^e, and/or N^e. Instead, here I use backward iterations to obtain N_{t+i+1}^e as a function of B^e by eliminating K^e given initial value of N^e and solve the optimal choice of B_t^e.

Eliminating K_t^e from (4) and (5) with changing time subscripts from t to $t+i$ gives us

$$\begin{aligned} N_{t+i+1}^e = &\left\{ \frac{R_{K,t+i+1} - R_{D,t+i+1}}{\underline{R_K} - R_{D,t+i+1}} (R_{D,t+i+1} - R_{B,t+i}) + (R_{B,t+i} - R_{D,t+i+1}) \right\} B_{t+i-1}^e \\ &+ \left\{ \frac{R_{K,t+i+1} - R_{D,t+i+1}}{\underline{R_K} - R_{D,t+i+1}} (R_{D,t+i+1} - R_{B,t+i+1}) + (R_{B,t+i+1} - R_{D,t+i+1}) \right\} B_{t+i}^e \\ &- \frac{1}{2}\chi \frac{R_{K,t+i+1} - \underline{R_k}}{R_{D,t+i+1} - \underline{R_k}} B_{t+i}^{e^2} + \frac{R_{K,t+i+1} - \underline{R_K}}{R_{D,t+i+1} - \underline{R_K}} R_{D,t+i+1} N_{t+i}^e. \end{aligned} \tag{8}$$

Iterate backward for N_{t+i}^e and get,

$$\begin{aligned} &N_{t+i+1}^e \qquad (9) \\ &= \sum_{j=0}^{i} \prod_{j=1}^{i} \left\{ \frac{R_{K,t+j+1} - \underline{R_K}}{R_{D,t+j+1} - \underline{R_K}} R_{D,t+j+1} \right\} \left\{ \frac{R_{K,t+j+1} - R_{D,t+j+1}}{\underline{R_K} - R_{D,t+i+1}} (R_{D,t+j+1} - R_{B,t+j}) + (R_{B,t+j} - R_{D,t+j+1}) \right\} B_{t+j-1}^e \\ &+ \sum_{j=0}^{i} \prod_{j=1}^{i} \left\{ \frac{R_{K,t+j+1} - \underline{R_K}}{R_{D,t+j+1} - \underline{R_K}} R_{D,t+j+1} \right\} \left\{ \frac{R_{K,t+j+1} - R_{D,t+j+1}}{\underline{R_K} - R_{D,t+i+1}} (R_{D,t+j+1} - R_{B,t+j+1}) + (R_{B,t+j+1} - R_{D,t+j+1}) \right\} B_{t+j}^e \\ &+ \sum_{j=0}^{i} \prod_{j=1}^{i} \left\{ \frac{R_{K,t+j+1} - \underline{R_K}}{R_{D,t+j+1} - \underline{R_K}} R_{D,t+j+1} \right\} \left\{ -\frac{1}{2}\chi \frac{R_{K,t+j+1} - R_{D,t+j+1}}{R_{D,t+i+1} - \underline{R_K}} \right\} B_{t+j}^{e^2} \\ &+ \prod_{j=1}^{i} \left\{ \frac{R_{K,t+j+1} - \underline{R_K}}{R_{D,t+j+1} - \underline{R_K}} R_{D,t+j+1} \right\} N_t^e, \qquad (10) \end{aligned}$$

where

$$\prod_{j=1}^{i} \left\{ \frac{R_{K,t+j+1} - \underline{R_K}}{R_{D,t+j+1} - \underline{R_K}} R_{D,t+j+1} \right\} = 1 \text{ for } \ i = 0$$

Thus, we have N_{t+i+1}^e as a function of bonds and return rates. Substitute this representation into N_{t+i+1}^e in (6) and take the first-order condition with respect to B_{t+i}. After this calculation, by taking a case of $i = 0$, we obtain

$$
\begin{aligned}
&\{\Lambda_{t,t+2}\theta^1 + \Lambda_{t,t+3}\theta^2 + \Lambda_{t,t+4}\theta^3 + ...\}\frac{R_{K,t+2} - \underline{R_K}}{R_{D,t+2} - \underline{R_K}} R_{D,t+2} \\
&\qquad\qquad\qquad\qquad\qquad\qquad \left\{\frac{R_{K,t+2} - R_{D,t+2}}{\underline{R_K} - R_{D,t+2}}(R_{D,t+2} - \underline{R_B}) + (R_{B,t+1} - R_{D,t+2})\right\} \\
&+ \{\Lambda_{t,t+1}\theta^0 + \Lambda_{t,t+2}\theta^1 + \Lambda_{t,t+3}\theta^2 + ...\}\left\{\frac{R_{K,t+1} - R_{D,t+1}}{\underline{R_K} - R_{D,t+1}}(R_{D,t+1} - \underline{R_B}) + (R_{B,t+1} - R_{D,t+1})\right\} \\
&+ \{\Lambda_{t,t+1}\theta^0 + \Lambda_{t,t+2}\theta^1 + \Lambda_{t,t+3}\theta^2 + ...\}\left\{-\chi\frac{R_{K,t+1} - \underline{R_K}}{R_{D,t+1} - \underline{R_K}}\right\} B_t = 0. \qquad (11)
\end{aligned}
$$

In order to have a recursive representation for $\{\Lambda_{t,t+2}\theta^1 + \Lambda_{t,t+3}\theta^2 + \Lambda_{t,t+4}\theta^3 + ...\}$ in (11), it is convenient to define Ω as

$$
\begin{aligned}
\Omega_{t+1} &= \frac{\Lambda_{t,t+2}\theta^1 + \Lambda_{t,t+3}\theta^2 + \Lambda_{t,t+4}\theta^3 + ...}{\Lambda_{t,t+1}\theta^0} \\
&= \beta\frac{U_c(C_{t+2}, L_{t+2})}{U_c(C_{t+1}, L_{t+1})}\theta + \beta^2\frac{U_c(C_{t+3}, L_{t+3})}{U_c(C_{t+2}, L_{t+2})}\theta^2 + \beta^3\frac{U_c(C_{t+4}, L_{t+4})}{U_c(C_{t+3}, L_{t+3})}\theta^3 + ... \,. \qquad (12)
\end{aligned}
$$

By taking a one period forward expression of the above and taking the difference of these, Ω can be written as

$$
\Omega_{t+1} = \beta\theta\frac{U_c(C_{t+2}, L_{t+2})}{U_c(C_{t+1}, L_{t+1})}\{1 + \Omega_{t+2}\}. \qquad (13)
$$

By using Ω to substitute out $\{\Lambda_{t,t+2}\theta^1 + \Lambda_{t,t+3}\theta^2 + \Lambda_{t,t+4}\theta^3 + ...\}$ in (11), we have a government bond demand equation from EO banks as

$$
\begin{aligned}
B_t^e = &\left\{\frac{R_{K,t+1} - \underline{R_K}}{R_{D,t+1} - \underline{R_K}}\chi(1 + \Omega_{t+1})\right\}^{-1} \\
&\left[\left\{(1 + \Omega_{t+1}) + \Omega_{t+1}\frac{R_{K,t+2} - \underline{R_K}}{R_{D,t+2} - \underline{R_K}} R_{D,t+2}\right\} R_{B,t+1}\right. \\
&- (1 + \Omega_{t+1}) R_{D,t+1} \\
&- \Omega_{t+1}\frac{R_{K,t+1} - \underline{R_K}}{R_{D,t+1} - \underline{R_K}} R_{D,t+2} R_{D,t+2} \\
&- (1 + \Omega_{t+1})\frac{R_{K,t+1} - R_{D,t+1}}{R_{D,t+1} - \underline{R_K}}(R_{D,t+1} - R_{B,t+1}) \\
&\left.- \Omega_{t+1}\frac{R_{K,t+2} - \underline{R_K}}{R_{D,t+2} - \underline{R_K}} R_{D,t+2}\frac{R_{K,t+2} - R_{D,t+2}}{R_{D,t+2} - \underline{R_K}}(R_{D,t+2} - R_{B,t+1})\right]. \qquad (14)
\end{aligned}
$$

Interpretation of this equation is as follows. The second line represents gross returns obtained from government bonds. To finance bond purchase, banks need to pay costs from deposit rates. The third and fourth lines indicate funding costs, namely deposit rates over two periods. Holding other things equal, when deposit rates are high, the demand for government bonds decreases. The last two lines represent risk effects on purchasing bonds associated with the VaR constraint. If the worst case return from capital holdings decreases, these two terms affect the demand for government bonds both from tighter VaR constraint effects which reduce bond demand and substitution effects from capital to bonds which increase bond demand. Lower R_B increases risks because it makes the VaR constraint tighter. The increase in R_K helps net worth accumulation and supports bond demand. Lower deposit rate alleviates insolvency risks and increases bond demand.

The VaR constraint for aggregate EO banks can be described as below.

$$(\underline{R_K} - R_{D,t+1})K_t^e + (R_{B,t} - R_{D,t+1})B_{t-1}^e + (R_{B,t+1} - R_{D,t+1})B_t^e - \frac{1}{2}\chi B_t^{e2} + R_{D,t+1}N_t^e \geq 0. \tag{15}$$

The aggregate net worth of EO banks evolves as below because only θ fraction of EO banks survive into the next periods. Net worth which is not carried to the next period because of exiting from the industry goes to the household.

$$N_t^e = \theta\{(R_{K,t} - R_{D,t})K_{t-1}^e + (R_{B,t-1} - R_{D,t})B_{t-2}^e + (R_{B,t} - R_{D,t})B_{t-1}^e - \frac{1}{2}\chi {B_{t-1}^e}^2 + R_{D,t}N_{t-1}^e\}. \tag{16}$$

2.1.2 Yield oriented (YO) banks

According to Hanson and Stein (2015), YO banks price long-term bonds differently from EO banks. The only difference is the expectation formation about the path of deposit rates, R_D. While EO banks rationally form expectations of R_D, YO banks consider at time t that today's level of $R_{D,t+1}$ at time t continues over the next period, time $t+1$, too. Then, at time $t+1$, they update their information about actual $R_{D,t+2}$ when they newly observe it and consider that the level will continue over the next period, $t+2$. Based on this assumption, I replace $R_{D,t+2}$ by $R_{D,t+1}$ in the EO's demand equation for B_t^e in (14). We obtain YO banks' demand for bond, B_t^y, as

$$
\begin{aligned}
B_t^y = &\left\{ \frac{R_{K,t+1} - \underline{R_K}}{R_{D,t+1} - \underline{R_K}} \chi (1 + \Omega_{t+1}) \right\}^{-1} \\
&\Bigg[\left\{ (1 + \Omega_{t+1}) + \Omega_{t+1} \frac{R_{K,t+2} - \underline{R_K}}{R_{D,t+1} - \underline{R_K}} R_{D,t+1} \right\} R_{B,t+1} \\
&- (1 + \Omega_{t+1}) R_{D,t+1} \\
&- \Omega_{t+1} \frac{R_{K,t+1} - \underline{R_K}}{R_{D,t+1} - \underline{R_K}} R_{D,t+1} R_{D,t+1} \\
&- (1 + \Omega_{t+1}) \frac{R_{K,t+1} - R_{D,t+1}}{R_{D,t+1} - \underline{R_K}} (R_{D,t+1} - R_{B,t+1}) \\
&- \Omega_{t+1} \frac{R_{K,t+2} - \underline{R_K}}{R_{D,t+1} - \underline{R_K}} R_{D,t+1} \frac{R_{K,t+2} - R_{D,t+1}}{R_{D,t+1} - \underline{R_K}} (R_{D,t+1} - R_{B,t+1}) \Bigg].
\end{aligned} \tag{17}
$$

By this formulation, we can interpret that yield-oriented banks care about the spread between long-term bonds yields and short-term interest rates as of today as opposed to EO banks who care about spreads in expected returns.[8] Even though the yield curve is upward-sloping, long-term bonds would be more attractive to the YO banks as long as today's deposit rate is low, but not necessarily to EO banks. Thus, the demand for long-term bonds from yield-oriented banks focuses more on current income.

The VaR constraint only includes $R_{D,t+1}$. Therefore, the VaR constraint and net worth evolution for YO banks become

$$
(\underline{R_K} - R_{D,t+1}) K_t^y + (R_{B,t} - R_{D,t+1}) B_{t-1}^y + (R_{B,t+1} - R_{D,t+1}) B_t^y - \frac{1}{2} \chi {B_t^y}^2 + R_{D,t+1} N_t^y \geq 0 \tag{18}
$$

and

$$
N_t^y = \theta \{ (R_{K,t} - R_{D,t}) K_{t-1}^y + (R_{B,t-1} - R_{D,t}) B_{t-2}^y + (R_{B,t} - R_{D,t}) B_{t-1}^y - \frac{1}{2} \chi {B_{t-1}^y}^2 + R_{D,t} N_{t-1}^y \}, \tag{19}
$$

respectively.

2.1.3 Definition of variables regarding asset returns and banks' balance sheet

For our convenience, we define variables outside the model regarding asset returns and banks' balance sheet variables as following. The term premium, tp,

[8] Though I replace $R_{D,t+2}$ by $R_{D,t+1}$ assuming that the banks are yield-oriented due to agency effects, the same model setting could be alternatively approached by extrapolative expectations in which the future short rate will be the same as today's. Literature regarding extrapolative expectations includes, for example, Fuster et al. (2010) and Lansing (2006).

$$tp_t = R_{B,t+1} - (R_{D,t+1} + R_{D,t+2})/2. \tag{20}$$

The spread between the bond return and the deposit return, bsp,

$$bsp_t = R_{B,t+1} - R_{D,t+1}. \tag{21}$$

Banks' asset, bal,

$$bal_t = B_{t-1} + B_t + K_t. \tag{22}$$

The leverage of banks, lev,

$$lev_t = bal_t/N_t. \tag{23}$$

The share of long-term bonds to total banks' asset, $bshare$,

$$bshare_t = (B_{t-1} + B_t)/bal_t. \tag{24}$$

B_t and N_t are the aggregate amount of bonds and the aggregate net worth respectively as defined later.

2.2 Households

The infinitely-lived representative household makes decisions on consumption, savings in the form of bank deposit holdings, and labor supply. It is excluded from the access to financial markets of capital stock holdings and government bonds. The household's utility in each period is presented in the following function,

$$U(C_t, L_t) = \frac{1}{1-\sigma}\left(C_t - \psi\frac{L_t^{1+\nu}}{1+\nu}\right)^{1-\sigma}, \tag{25}$$

where C_t is consumption at time t, L_t is labor at time t, σ is the relative risk aversion rate, ψ is the weight assigned to labor, and ν is the inverse of Frisch elasticity. I assume a GHH utility function to eliminate wealth effects on labor supply.

The budget constraint of the household is given by the following equation.

$$C_t + D_t = w_t L_t + R_{D,t} D_{t-1} - T_t + \pi_t^F + \pi_t^B. \tag{26}$$

w_t is the wage at time t, π_t^F is the profit from goods producers at time t and π_t^B is net worth from exiting banks returned to the household at time t. T_t is a lump-sum tax at time t. We assume that the deposit rate is the risk-free rate. π_t^B is given by

$$\pi_t^B = (1-\theta)N_t. \tag{27}$$

The household maximization problem is given by

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, L_t) \tag{28}$$

subject to (26), where E_0 denotes the expectation operator at time 0. $\beta \in (0,1)$ is the discount factor. The first-order conditions associated with the household maximization problem are given by the derivative of the utility by C_t,

$$U_c(C_t, L_t) = \left(C_t - \psi \frac{L_t^{1+\nu}}{1+\nu}\right)^{-\sigma}, \tag{29}$$

the Euler equation,

$$U_c(C_t, L_t) = \beta R_{D,t+1} U_c(C_{t+1}, L_{t+1}), \tag{30}$$

the derivative of the utility by L_t,

$$U_L(C_t, L_t) = \left(C_t - \psi \frac{L_t^{1+\nu}}{1+\nu}\right)^{-\sigma} (-\psi L_t^{\nu}), \tag{31}$$

and intratemporal decision,

$$-\frac{U_L(C_t, L_t)}{U_c(C_t, L_t)} = w_t. \tag{32}$$

Ω under this utility function in (13) is,

$$\Omega_t = \beta\theta \left\{ \frac{C_t - \psi \frac{L_t^{1+\nu}}{1+\nu}}{C_{t+1} - \psi \frac{L_{t+1}^{1+\nu}}{1+\nu}} \right\}^{\sigma} (1 + \Omega_{t+1}). \tag{33}$$

2.3 Firms/goods producers

Goods producers produce consumption goods and investment goods, and sell them to the household and capital producers. They hire labor from the household and borrow capital from banks. Both the input and output markets of goods producers are assumed to be competitive. Production technology is given by

$$Y_t = \exp(A_t) K_{t-1}^{\xi} L_t^{1-\xi}. \tag{34}$$

Y_t is output at time t and A_t represents the technology level at time t. The productivity shock process is formulated with a persistency parameter of ρ_A as,

$$A_t = \rho_A A_{t-1} - \epsilon_t^A. \tag{35}$$

First order conditions for goods producers yield the marginal productivity of capital,

$$MPK_t = \xi \frac{Y_t}{K_{t-1}} \tag{36}$$

and labor demand,

$$w_t = (1-\xi)\frac{Y_t}{L_t}. \tag{37}$$

The return on capital is defined as,

$$R_{K,t+1} = MPK_{t+1} + 1 - \delta. \tag{38}$$

2.4 Capital producers

Capital producers produce capital from investment goods, I_t, which are outputs from goods producers. They sell their outputs to banks. No adjustment costs are assumed here. Therefore, the output of capital producers becomes

$$K_t = (1-\delta)K_{t-1} + I_t. \tag{39}$$

2.5 The government

The government collects lump-sum tax T_t from the household and issues long-term (two-period) government bonds B_t to finance its repayment of bonds issued in the previous period and the period before the previous including interest rate costs, and government expenditure G_t. The government budget constraint is,

$$R_{B,t-1}B_{t-2} + R_{B,t}B_{t-1} + G_t = T_t + B_{t-1} + B_t. \tag{40}$$

The tax rule is given by following two equations.

$$T_t = \tau_t Y_t. \tag{41}$$

$$\tau_t = \rho_\tau * \bar{\tau} + (1-\rho_\tau) * \tau_{t-1} + \gamma(\frac{B_{t-1}}{Y_t} - \frac{B_{ss}}{Y_{ss}}). \tag{42}$$

Tax rate, τ_t, reacts to the deviation of the ratio of government bonds to output from the steady state by a parameter, γ, with the baseline rate, $\bar{\tau}$. Government expenditures are given exogenously,

$$G_t = \bar{g}. \tag{43}$$

2.6 Market clearing

EO banks and YO banks are populated by portions of (1-α) and α respectively so that the sum of these is unity. The aggregate demand for government bonds is,

$$B_t = (1-\alpha)B_t^e + \alpha B_t^y. \tag{44}$$

By the same logic, the aggregate demand for capital is,

$$K_t = (1-\alpha)K_t^e + \alpha K_t^y. \tag{45}$$

The supply of capital is given by capital producers' output. Aggregate net worth of banks is given by

$$N_t = (1-\alpha)N_t^e + \alpha N_t^y. \tag{46}$$

Finally, because of long-term government bond holding costs of both EO and YO banks, the resource constraint of the entire economy becomes,

$$C_t + I_t + G_t + (1-\alpha)\frac{1}{2}\chi {B_{t-1}^e}^2 + \alpha\frac{1}{2}\chi {B_{t-1}^y}^2 = Y_t. \tag{47}$$

2.7 Equilibrium Conditions

An equilibrium consists of a set of prices, $\{w_t, R_{K,t}, R_{D,t}, R_{B,t},\}_{t=0}^{\infty}$, and the allocations $\{C_t, L_t, B_t^e, B_t^y, K_t^e, K_t^y, Y_t\}_{t=0}^{\infty}$, for a given government policy $\{G_t, \tau_t\}_{t=0}^{\infty}$, realization of exogenous variable $\{\epsilon_t^A\}_{t=0}^{\infty}$, expected worst-case return $\{\underline{R_K}\}$, and initial conditions $\{B_{-1}^e, B_{-1}^y, K_{-1}^e,$

$K^y_{-1}, D^e_{-1}, D^y_{-1}, N^e_{-1}, N^y_{-1}, R_{D,0}\}$ such that for all t: (i) the household maximizes its utility given prices; (ii) each type of banks maximizes their profits given prices and expected worst case returns; (iii) goods producers maximize their profits given prices; (iv) capital producers maximize their profits given prices; (vi) the government budget constraint holds; and (vii) all markets clear.

3 Quantitative analysis

In this section we see quantitative implications of our model economy. Using the calibrated model, we compute impulse responses of macroeconomic variables to shocks. Especially, we consider different population shares of two types of banks and investigate how they change dynamic paths of the economy.

To summarize, implications found here are as follows. First, the existence of YO banks makes recovery path after negative productivity shock hits the economy more sluggish. Second, as Hanson and Stein (2015) suggest, we observe lower term premium in the long term bond interest rate in YO economy.

3.1 Calibration

Table 1 lists the choice of parameter values for our baseline model. We calibrate commonly used parameters so that they are within conventional values. There are banking sector parameters in addition to these. I use banks survival probability θ referring to Aoki and Sudo (2013) which is smaller than Gertler and Karadi (2011). A banking parameter which is specific to our model is the size parameter of long-term bond holding cost χ. I calibrated this parameter so that a steady state value of bond return do not surpass that of capital return which is interpreted as risk premium of capital holding. $\underline{R_K}$ is the worst case return of capital. I take a similar value to Aoki and Sudo (2013) which allows the VaR constraint to bind always. Calibrations are set so that the steady state value of bond outstanding becomes positive.

3.2 Impulse response

Figure 2 indicates impulse responses to the negative productivity shock. First, we look at responses which are observed in the economy where all banks are EO type (EO economy,

Parameters	Value	Description
β	0.98	Discount rate
σ	2.5	Relative risk aversion rate
ψ	6	Relative utility weight of labor
ν	1	Inverse of Frisch elasticity
$\underline{R_K}$	0.8	Worst case gross return of capital
χ	0.0005	Size parameter of long-term bond holding cost
θ	0.9	Survival rate of banks
ξ	0.35	Capital share
δ	0.05	Depreciation rate
$\bar{\tau}$	0.35	Steady state tax rate
$\bar{g}$	0.1	Steady state govenment expenditure
γ	0.04	Response parateter of tax rate to bond to output ratio
$\frac{B_{ss}}{Y_s s}$	3.30	Steady state bond to output ratio
ρ_A	0.5	Autoregressive parameter of productivity shock
ρ_T	0.5	Autoregressive parameter of tax rule

Table 1: Parameters

$\alpha = 0$), and second, we see the economy where all banks are YO type (YO economy, $\alpha = 1$). The solid line indicates EO economy and the dotted line indicates YO economy.

3.2.1 EO economy

By the negative shock, labor input decreases while capital stock being used at time t does not move because this is determined at the previous period. The negative productivity shock reduces the real wage, and labor supply decreases as well because we assume a GHH utility function where the wealth effect is eliminated. This implies lower capital return because the marginal productivity of capital decreases both from negative productivity and less labor input.

Because of reduced capital return, net worth of the next period has to decrease through the net worth evolution. Lowered net worth tightens the VaR constraint. In order to satisfy tighter VaR constraint, there are primarily two variables to adjust. The amount of capital stock for banks to hold, K_t^e, needs to be smaller and the deposit rate, $R_{D,t+1}$, needs to be lower. Reduced capital stock demand actually dampens capital investment significantly. The deposit rate functions in a little complicated way to resource allocations. The lowered deposit rate has to be consistent with lower consumption growth rate from today to the next period. This implies that consumption of today has to increase given the life time wealth effect. The output itself is governed by today's productivity shock, today's labor input, and capital stock which was predetermined at the previous period. A sudden drop of investments has to be covered by less decreasing degree (or increase) of consumption to be consistent with output drop degree due to crowd-in of consumption.

Next, we see impacts on bond interest rates. Lowered deposit rate affects bond pricing. This is important for banks' profits. Long-term bond interest rate is mainly determined by risk neutral deposit rate path and risk associated term.

To see this, R_B becomes the following in the steady state from (13) and (14).

$$R_B^* = R_D^* + \frac{\chi B^*}{1 + \beta\theta \frac{R_K^* - \underline{R_K}}{R_D^* - \underline{R_K}} R_D^*}. \tag{48}$$

A superscript star in this equation denotes steady state values of each variable. From the first term, lower deposit rate directly reduce bond rate. The second term is decomposed to bond supply amount, capital return, deposit return, and the worst case capital return. Lowered deposit rates alleviate risks of insolvency and allow bond return for becoming less. Therefore, a decrease in the deposit rate leads to lower the long-term bond interest rate both from the first term, risk neutral costs of funding, and the second term, risk premium parts associated with the VaR constraint together with bond supply. An increase in R_K helps for banks satisfy the VaR constraint. This allows R_B to decrease in purchasing bonds. What will happen when the bond supply changes? To absorb the bond supply from the government, the spread between the bond return and the deposit rate needs to be kept large enough.

Next, we look at the supply side of long-term bonds. Lowered bond returns imply less costs for the government. Even though less output reduces tax revenues, this interest rate cost effects leads to less bond supply. In the equilibrium, the amount of bonds becomes less in the economy.[9] Less supply gives pressures to reduce bond interest rates. In Hanson and Stein (2015), risk premium of the government bond return is determined by exogenously given bond supply and the variance of the deposit rate based on a mean-variance-type utility function of financial investors. On the other hand, endogenously determined less supply of bonds decreases bond interest rates through bond holding costs affected by the VaR constraint.

[9] When we assume bond returns are risk free, returns are predetermined. However, in our model, this is not the case.

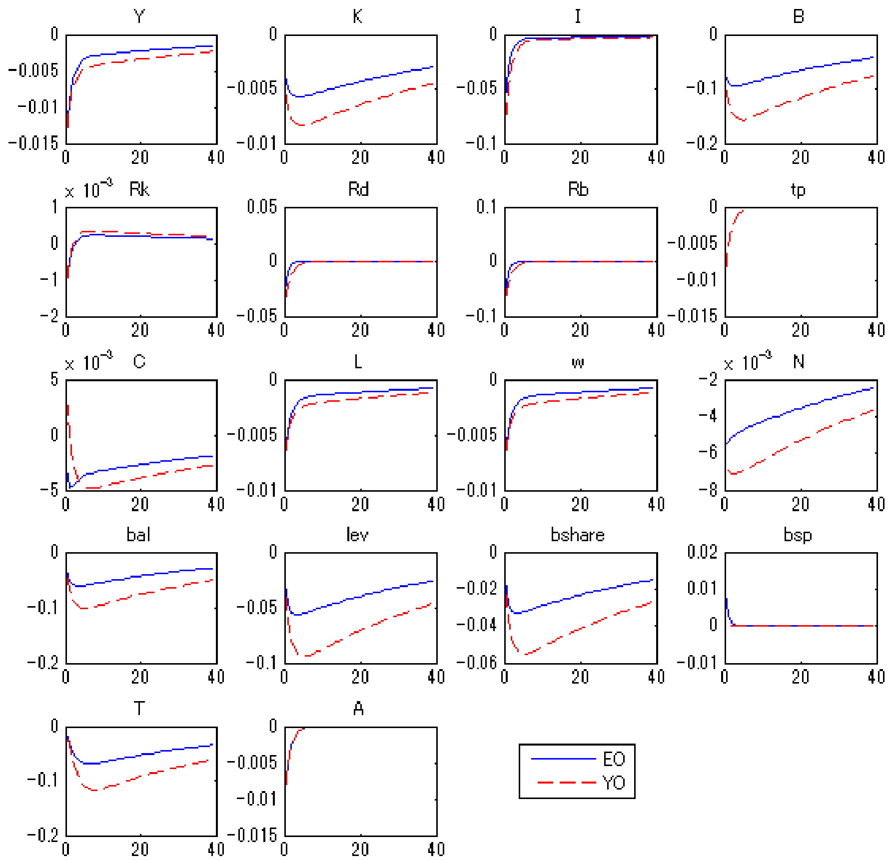

Figure 2: Impulse response to negative productivity shock

Impulse response to 1% negative productivity shock. The solid line indicates the economy where all banks are EO type (EO economy, $\alpha = 0$). The dotted line indicates the economy where all banks are YO type (YO economy, $\alpha = 1$). 0.01 in the vertical axis scale amounts to 1%. Return and spread variables, R_K, R_D, R_B, tp, and bsp are in %point differences from their steady states. Otherwise, variables are shown in % deviation from their steady state levels.

3.2.2 YO economy

As we observe in figure 2, YO economy shows sluggish recovery after the negative productivity shock. In this part, I want to investigate backgrounds behind this difference.

At period 0 when negative productivity shock occurs, outputs of EO and YO economies decrease to similar degrees. Lowered marginal productivity pushes down capital demand and labor demand. A key is how different bond pricings affect dynamics of the economy. The spread between bond interest rate and deposit rate in YO economy becomes smaller than EO economy mainly because of smaller term premium. Less expected bond spread implies less profit and net worth to be accumulated for YO banks. Lower bond rate tightens the VaR constraint and allows YO banks to demand less capital stock at the very period of negative productivity shock emerges.

Major differences come from unexpected ex-post behaviors of deposit rates for YO banks. Even though YO banks expect a flat path of deposit rates over two periods, the deposit rate gradually recover over time as opposed to their expectations. Thus, actual spread obtained from bond holding becomes less because of actual deposit rate path. This reduces YO banks' profits and erodes net worth for the next period.

Since lower net worth is a state variable, they choose a smaller level of capital, which makes investment smaller. As a result, output decreases. By crowding-in effects between investment and consumption, consumption needs to offset investment drop to some extent. This offsetting effect of consumption needs to go with relatively deeper interest rate drop in YO economy compared to EO economy. Consumption in YO economy is higher than EO economy by this reason during early periods after negative productivity shock hits the economy.[10] YO banks price bonds based on relatively lower deposit rate actually observed again. Therefore, bond interest rates stay lower than EO economy and continue to give differences between two economies.

A next question is how the bond supply affects the economy. As I just described, long-term bond interest rate becomes lower. The government budget constraint in (40) is governed by this interest rate. Newly determined bond interest rate on the left hand side lets the government issues less bonds on the right hand side. Less bond supply induces less spread between bond interest rate and deposit rate from the bond demand equation (17). By this logic, profits obtained from bond holding become less compared with EO case, the VaR constraint becomes tighter, YO banks are allowed to choose less capital, and output shows persistently lower path. If one looks at impulse responses regarding banks' balance sheets, less net worth allows less total balance sheet size, less profit margin from bond holdings allows less leverages, and we observe less asset holding share of bonds to capital holdings with the effects from less bond supply.

To summarize, the existence of YO banks makes recovery processes more sluggish, lower term premium in the long-term bond interest rate emerges in YO economy, less supply of the government bond generates even less bond interest rates.

[10] In the longer run, less output implies less life time labor income. Long-run consumption in YO economy is lower than EO's.

4 Experiment

In this section, we discuss what characteristics of the economy close differences between EO and YO economy in impulse responses. As we have seen, VaR effects from eroded ex-post net worth are one of the key mechanisms to give these differences.

Even when the two economies start with the same amount of net worth, differences should be magnified if the VaR constraint is tighter. Therefore, a natural candidate is the worst case return of capital, $\underline{R_K}$. Another candidate is the effect from bond supply side settings. In our base model, tax rate is a function of bond to output ratio which is necessary for this model to find a unique solution. If the government were more sensitive to fiscal austerity and tax rate reaction to the increase in bond to output ratio, γ, were stronger, bond pricing should be affected from demand and supply relation.

4.1 Less severe worst return of capital

First, we see impacts from less severe worst case return of capital. Figure 3 shows impulse responses when $\underline{R_K}$ is lifted from 0.8 in the benchmark case of the section 3 to 0.9.

Output difference becomes smaller in this case. Increase in $\underline{R_K}$ has two ways to affect banks' portfolio choices[11]. First one is looser leverage constraint which allows banks to have larger balance sheet sizes given net worth. Second one is the substitution effect in the VaR constraint by which banks shift their assets more to capital holdings. Therefore, investment shows a less drop than the benchmark case. This implies less crowding-in effect of consumption. Less consumption needs to be consistent with the higher deposit rate compared to the benchmark case.

Less drop of the deposit rate implies its flatter path toward the steady state. Because of this, negative effects on YO banks' net worth from irrational expectation formations are muted. Also, shifts from bonds to capital mitigate this impact. Even more, looser leverage constraint gives less magnification effects from net worth erosions. Therefore, output difference between two economies becomes smaller.

[11] See Ono et al. (2016) for income and substitution effect on portfolio choice.

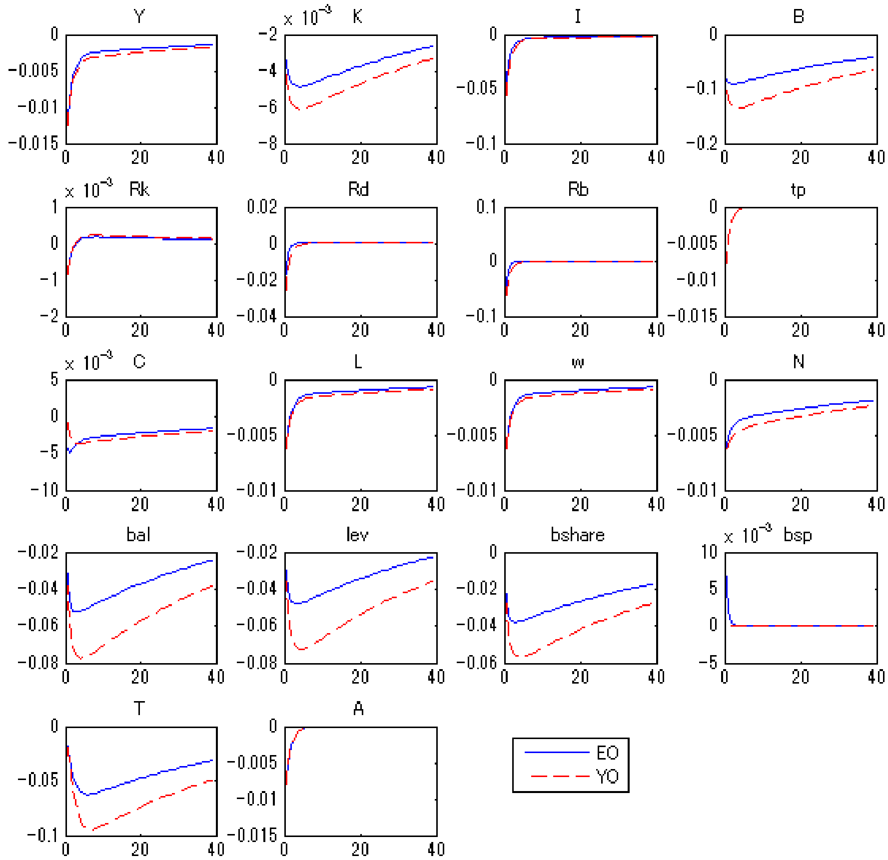

Figure 3: Impulse response to negative productivity shock with less severe worst case capital return

Impulse responses to 1% negative productivity shock in an economy with worst case capital return ($\underline{R_K} = 0.9$). The solid line indicates the economy where all banks are EO type (EO economy, $\alpha = 0$). The dotted line indicates the economy where all banks are YO type (YO economy, $\alpha = 1$). 0.01 in the vertical axis scale amounts to 1%. Return and spread variables, R_K, R_D, R_B, tp, and bsp are in %point differences from their steady states. Otherwise, variables are shown in % deviation from their steady state levels.

4.2 Higher tax rate reaction to bond to output ratio

Here we argue effects from the increase in the tax rate reaction to bond to output ratio, γ, in (42). In this case the supply side of the bond market gives changes of the equilibrium while the previous experiment is related with the asset demand side. Figure 4 shows impulse responses when γ increases from 0.4 in the benchmark case of the section 3 to 0.8.

Overall impacts on both EO and YO cases from negative productivity shock are smaller than the benchmark case and differences between two cases are smaller as well. Higher γ

implies tax adjust more than the benchmark case so as to satisfy the flow of government budget constraint (40). Therefore, variance of B becomes smaller than the benchmark case. In the VaR constraint, smaller drop of B implies smaller necessity of adjustment from R_D. Thus, negative impacts on output become less. Consequently, tax does not decrease much. Smaller variance of the deposit rate lets its path flatter. A flatter deposit rate recovery path makes difference between EO and YO banks in bond pricing smaller. Therefore, difference of term premium becomes smaller, ex-post net worth erosion of YO banks becomes muted, and difference of output is muted. If tax is lump-sum as in a standard RBC model, tax changes do not affect allocations. However, this model includes the supply effect of bonds from banks' optimization problem under the VaR constraint. Therefore, Ricardian equivalence does not hold here.

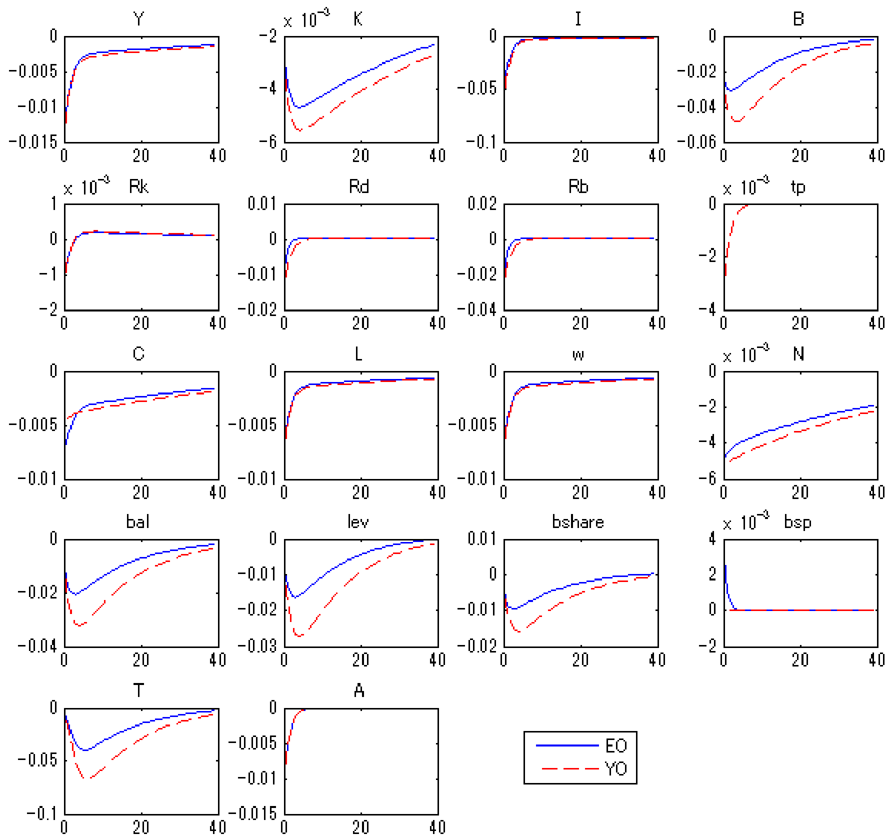

Figure 4: Impulse response to negative productivity shock with higher tax rate response to bond to output ratio

Impulse responses to 1% negative productivity shock in an economy with higher tax rate response to bond to output ratio ($\gamma = 0.8$). The solid line indicates the economy where all banks are EO type (EO economy, $\alpha = 0$). The dotted line indicates the economy where all banks are YO type (YO economy, $\alpha = 1$). 0.01 in the vertical axis scale amounts to 1%. Return and spread variables, R_K, R_D, R_B, tp, and bsp are in %point differences from their steady states. Otherwise, variables are shown in % deviation from their steady state levels.

5 Conclusion

I examined general equilibrium consequences by putting a partial equilibrium model of yield-oriented banks motivated by Hanson and Stein (2015) into a RBC model with banks under the VaR constraint. We still see negative term premium of long-term bonds in the general equilibrium economy with YO banks. In addition, output recovery after the negative productivity shock becomes more sluggish changing banks' portfolio size and allocations. Output differences between the economy with the existence of only rational EO banks and that of irrational YO banks close when banks become optimistic about the worst case capital return through banks' portfolio choices. Fiscal policy has non-negligible effects. Under an economy in which the fiscal authority is more sensitive to the increase in bond outstanding, variance of deposit rates is smaller and they track flatter paths during the recovery after negative productivity shocks occur. This consequently closes gaps in bond pricing between EO and YO banks. Thus, output differences between two types of economies become smaller.

Finally, this model is a real model abstracting nominal impacts. Also, bond supply in the market is adjusted by the central bank in actual economies. These considerations are remained for further research.

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A Appendix

For clarification, time notations used in Dynare codes for (1) and (2) are set as follows. First, because net worth, N^e, is a state variable, its time notation in (1) is coded by one-period lag in order to guarantee that it is pre-determined in a timing of banks' choosing K_t^e and B_t^e. Therefore, in Dynare code we have

$$K_t^e + B_{t-1}^e + B_t^e = D_t^e + N_{t-1}^e. \tag{49}$$

Also, time notation for N^e in the net worth law of motion (2) is coded by one-period lag. In addition, since D_{t+1}^e, deposit rate from time t to $t+1$, is known at time t, we code this as D_t^e. Dynare code for (2) is

$$\begin{aligned} N_t^e =& R_{K,t+1} K_t^e + R_{B,t} B_{t-1}^e + R_{B,t+1} B_t^e \\ & - \frac{1}{2} \chi B_t^{e^2} - R_{D,t} D_t^e. \end{aligned} \tag{50}$$

Because N^e is coded with one-period lag in (49), return on capital which flows through based on (50) into net worth in the balance sheet constraint in a timing of banks' choosing K_t^e and B_t^e is not $R_{K,t+1}$ but $R_{K,t}$. All of N^e, N^y, and R_D included in other model equations than shown above are written by one-period lag in Dynare codes.