

学術情報リポジトリ

Is Direct Underwriting of Public Bonds by the Central Bank an Effective Policy in Japan?

メタデータ	言語: eng
	出版者:
	公開日: 2015-03-05
	キーワード (Ja):
	キーワード (En):
	作成者: Yoshida, Motonori
	メールアドレス:
	所属:
URL	https://doi.org/10.24729/00002470

Is Direct Underwriting of Public Bonds by the Central Bank an Effective Policy in Japan?

Motonori Yoshida

Discussion Paper New Series No.2015-1 February 2015

Is Direct Underwriting of Public Bonds by the Central Bank an Effective Policy in Japan?*

Motonori Yoshida^{**} Graduate School of Economics, Osaka Prefecture University

Abstract

Direct underwriting of public bonds by the central bank has the potential to support the Japanese economy and government finance and to improve the efficiency of added-value distribution in Japan, while also maintaining the current levels of government expenditures and public pension system. Accordingly, this study elucidates the effects of this policy using a dynamic computable general equilibrium OLG model.

This study's results demonstrate the following. First, failure of the Japanese economy and government finance occurs in the case where public bonds are absorbed by the market. However, in the case where public bonds are directly underwritten by the central bank, the economy and government finance are fundamentally sustainable. This is due to the fact that in the latter case, payment of the central bank's seigniorage to the national treasury improves government finance. Second, a downward shift in the rate of time preference of representative households improves the economy and government finance. Third, if the economy and government finance are sustainable, there will be a continuous rise in GNI per capita and physical capital stock per unit of effective labor due to the decrease in total population and working age population along with advances in production technology. Fourth, if the economy and government finance are sustainable, the utility levels of future generations will somewhat exceed that of the base generation, due to the growth in physical capital stock per unit of effective labor that accompanies the aging of society.

JEL Classification Numbers: C68; E27; E63; H55; H63; H68

Keywords: Fiscal sustainability; Direct underwriting of public bonds; Central bank; Seigniorage; Dynamic computable general equilibrium; Overlapping generations model

^{*} I am grateful for financial support from the Japan Society for the Promotion of Science, Grant-in Aid for Science Research (C), 25380309.

^{**} Associate Professor of Graduate School of Economics, Osaka Prefecture University, 1-1 Gakuen-cho, Naka-ku, Sakai-shi, Osaka, 599-8531, Japan. E-mail address: myoshida@eco.osakafu-u.ac.jp

1. Introduction

Currently, many experts including academic researchers are questioning the sustainability of the Japanese economy and government finance (see Section 2). In actual fact, the ratio of fiscal balance of the general government¹ to GDP was approximately -9.8% in Japan in 2012 (calendar year). This figure was the worst among the G7 countries, namely the United States (U.S.), the United Kingdom (U.K.), Germany, France, Italy, Canada, and Japan. Moreover, the general government's outstanding debt-to-GDP ratio was approximately 218.8%. This figure was also the worst among the G7 countries.²

Accordingly, in order to examine this issue in detail, I show the transitions in the balance of net lending (+) / net borrowing (-) and net stock of financial assets by sector of economy in Figures 1 and 2, the changes in primary balance by subsector of public sector in Figure 3, and an international comparison of external asset balance as of 2012 in Figure 4. When these graphs are collectively observed, the following facts become clear. 1) Among the respective sectors in Japan, the public sector balance of flow and net stock of financial assets (liabilities) both continue to be in extremely poor condition. 2) Furthermore, the central government's primary deficit continues within the public sector. 3) However, in contrast to the government's poor financial situation, in the Japanese economy as a whole, the buoyant financial situation of the private sector sufficiently compensates for the poor performance of the public sector in terms of both flow³ and stock. 4) In particular, Japan's external asset balance is the highest in the world.⁴ As a summary of the above points 1-4, it is possible to state that although the Japanese economy as a whole possesses global top-class economic power, the public sector, which is a part of the Japanese economy, is in the worst financial condition of all of the major developed nations. In other words, Japan is wrongly distributing its own added value. Furthermore, I show the changes in financial indicators of Japan's central bank, the Bank of Japan (BOJ) in Table 1, and the changes in the central government's total annual expenditure, debt redemption expenses, and interest payments on government bonds in Table 2. These two tables show the following. 1) Owing to the policy of monetary easing implemented continuously by the BOJ since 1998, among the BOJ's assets, the outstanding Japanese government bonds (JGBs) and the ratio of those to total as-

 $^{^{\}rm 1}$ General government consists of the central government, local governments, and social security funds.

² These financial indicators are based on those of the Ministry of Finance: http://www.mof.go.jp/ tax_policy/summary/condition/ (Accessed on January 7, 2015).

 $^{^{\}scriptscriptstyle 3}$ The Japanese economy has been in a current account surplus for more than the past thirty years.

 $^{^4}$ Japan's external asset balance has been the highest in the world for more than the past twenty years.

sets the JOB holds are both increasing rapidly. 2) Most of the BOJ's receipt of interest on JGBs (the BOJ's seigniorage) is paid to the national treasury,⁵ and the amount is basically continuing to rise. 3) Meanwhile, debt redemption expenses accounts for an extremely high proportion of the central government's annual expenditure, and this amount is also continuing to rise.

On the basis of the above observations of the Japanese economy and government finance, Japan needs to consider the implementation of a financial and monetary policy in which the BOJ directly underwrites public bonds (including local government bonds⁶)⁷, although this may initially seem reckless. Such a policy seems necessary because it has the potential to improve the efficiency of added-value distribution in Japan as a whole, via the channel of the BOJ's payment of interest on public bonds to the national treasury.

Many prior studies have demonstrated negative simulation results in relation to the sustainability of Japanese government finance until now; for example, Ihori et al. (2001), Doi et al. (2011), Ito et al. (2011), Ihori et al. (2006), and Shimazawa and Oguro (2010). Moreover, such studies have indicated a need for Japan to raise the ratio of government revenue to GDP to roughly 50% or to drastically cut public annual expenditure in order to maintain government finance (see Section 2). However, to the author's knowledge, no research has used a dynamic computable general equilibrium OLG model (DCGE-OLG model) to examine the effects of the above-described policy on public bonds, targeting the actual Japanese economy. Additionally, note that an OLG model inherently represents an overlapping generations model.

For this reason, I elucidate the effects of a policy in which the BOJ directly underwrites public bonds, using simulation analysis. There are two objectives of such analysis, as follows. 1) To evaluate whether the Japanese economy and government finance can be made sustainable with this "third way" that is neither raising taxes nor cutting annual expenditure. 2) To investigate whether this policy can improve the efficiency of added-value distribution in Japan. Furthermore, I use the above-mentioned DCGE-OLG model as a method of analysis. This method is used because it is possible to observe in detail the reactions of the relevant economic agents to changes in exogenous variables such as fiscal policy, the repeated effects on the government sector by multiple variables endogenously determined within the model, the transition process occurring in society, and the welfare and financial burdens of each generation. Considering these

 $^{^5\,}$ This measure is based on Article 53 of the Bank of Japan Act.

⁶ Hereinafter, as explained here, "public bonds" includes local government bonds. However, "government bonds" refers to bonds issued by the central government.

⁷ Market absorption of JGBs is obligatory under Article 5 of the Public Finance Act.

factors, this method differs from other simulation analyses that assigns various socioeconomic variables as exogenous variables.

The rest of the paper is organized as follows. In Section 2, related literature and the aim of this study are explained. Section 3 describes the model used in this study. Section 4 provides an explanation of the parameters and data used in this study. Section 5 presents the simulation results. Finally, Section 6 concludes the paper.





Note: Households include private unincorporated enterprises and private non-profit institutions serving households.

Source: By the author, using data from the National Accounts (Cabinet Office).



Figure 2. Net Stock of Financial Assets by Institutional Sector of Japan Note: Households include private unincorporated enterprises and private non-profit institutions serving households.

Source: By the author, using data from the National Accounts (Cabinet Office).



Figure 3. Primary Balance by Governmental Institutional Sector of Japan Source: By the author, using data from the National Accounts (Cabinet Office).





Source: By the author, using data from the Principal Global Indicators (IMF):

http://www.principalglobalindicators.org/Pages/Default.aspx (Accessed on December 16, 2014).

					(Unit:	billion yen)
FY	2008	2009	2010	2011	2012	2013
Financial statement item of BOJ						
(Statement income and appropriato	n of net incon	ne)				
Interest and discounts on JGB	648	600	622	620	623	806
Net income	300	367	52	529	576	724
Payment to the government	255	349	44	503	547	579
(Balance sheet: assets)						
JGB	64,266	73,066	77,299	87,247	125,356	198,337
Total assets	123,889	121,824	142,363	139,457	164,813	241,580
JGB ratio to total assets	0.519	0.600	0.543	0.626	0.761	0.821
JGB outstanding	788,931	826,517	869,354	906,209	936,742	969,452
Ratio of holdings by BOJ	0.081	0.088	0.089	0.096	0.134	0.205

Table 1. Net Income of BOJ, Payment to the Government by BOJ, JOB's Total Assets

Notes: (1) BOJ indicates the Bank of Japan, and JGB indicates Japanese government bonds, respectively.

(2) JGB outstanding figures are as of the end of every fiscal year. In addition, JGB outstanding includes treasury discount bills.

Sources: (1) Data from the Ministry of Finance: http://www.mof.go.jp/jgbs/reference/gbb

/data.htm (Accessed on December 17, 2014).

(2) Data from the Bank of Japan: http://www.boj.or.jp/about/account/index.htm/

(Accessed on December 17, 2014).

Table 2. Interest Payments on JGBs and General Account Total Expenditure: Central Government (Initial Budget)

							(Unit: bil	lion yen)
FY	2006	2007	2008	2009	2010	2011	2012	2013
Debt redemption expenses	18,762	20,999	20,163	20,244	20,649	21,549	21,944	22,242
JGB interest payments	8,500	9,043	8,935	9,033	9,412	9,626	9,581	9,625
General account total expenditure	79,686	82,909	83,061	88,548	92,299	92,412	90,334	92,612

Note: "JGB interest payments" include financing bills discount expense.

Sources: Debt Management Report (issued each fiscal year) (Ministry of Finance)

2. Related literature and aim of this study

As stated in Section 1, I use a DCGE-OLG model to simulate how a policy of direct underwriting of public bonds (hereinafter, "DUPB") by the BOJ would effect the sustainability of the Japanese economy and government finance and the welfare of Japanese citizens.

Therefore, the related literature can be classified into three areas in connection with this study: 1) analysis related to fiscal sustainability, 2) analysis related to monetization of government debt, and 3) analysis based on dynamic general equilibrium simulation using an OLG model.

Accordingly, Section 2.1 provides an overview of research in these three areas. Next, based on Section 2.1, Section 2.2 positions this research and states the aim of this study.

2.1 Related literature

2.1.1 Government fiscal sustainability

First, Hamilton and Flavin (1986) and related literature are discussed. Hamilton and Flavin (1986) indicated the conditions required for government finance that maintains a fiscal deficit to be sustainable.⁸ In concrete terms, they defined the conditions as follows: if the transversality condition is satisfied, that is to say if the discounted present value of the indefinitely rolled-over outstanding government debt converges to zero,⁹ such fiscal management is sustainable; in other words, the intertemporal budget constraint is fulfilled.¹⁰ Furthermore, they regressed the outstanding U.S. public bonds on interest rate on public bonds and the lag variables of outstanding public bonds and

⁸ In further detail, they indicated the conditions required for the government's fiscal management not to break the present-value government borrowing constraint (the expected sum total of the discounted present value of annual expenditure from the present to the future, excluding interest payments, cannot exceed that of the annual revenue).

⁹ In further detail, if the rate of increase of outstanding public bonds falls below the interest rate on public bonds.

¹⁰ The Ricardian Equivalence Theorem and Domar (1944)'s condition are as other representative approaches that consider fiscal sustainability. The former is a theorem that states that if economic agents are correctly conducting expectation formation (correctly recognizing the tax increase at the time of redemption of public bonds), taxation and public bonds, which are tools for raising funds for government expenditures, bring the same outcome (see, for example, Seater(1993) for details). The contents of the latter are as follows: it is necessary for the rate of increase of outstanding public bonds to be lower than the rate of economic growth (also, in conditions where the primary balance is maintained, the interest rate on public bonds must be lower than the rate of economic growth) in order not to diverge the ratio of outstanding public bonds to GDP. Furthermore, it is self-evident that fiscal sustainability is possible if the above theorem and condition are met. However, Ihori et al. (2001) proved that the Ricardian Equivalence Theorem was not completely fulfilled in Japan in the 1970-1990s, and Abel et al. (1989) proved that the real interest rate exceeded the rate of economic growth in the major developed nations, including Japan, in the 1960-1980s.

primary balance,¹¹ and measured the discounted present value of the U.S. government's indefinitely rolled-over outstanding government debt. As a result, they demonstrated that the U.S. government was implementing sustainable fiscal management during the period of the data sample (1960 - 84). In addition, Fukuda and Teruyama (1994) used Hamilton and Flavin (1986)'s method to analyze the sustainability of Japanese government finance between 1888 and 1992. The results of their analysis showed that fiscal sustainability is supported during the post-World War II period, whereas during the prewar and wartime periods, fiscal sustainability is not supported. Subsequently, Fukuda and Teruyama (1994) also conducted an analysis (sample period of 1985 - 92) using the cointegration test. ¹² As a result, the same outcome was obtained as when using Hamilton and Flavin (1986)'s method.

Next, Bohn (1998) and related literature are discussed. Bohn (1998) presented a method for examining the sustainability of government finance by regressing the ratio of outstanding public debt to GDP on the ratio of primary balance to GDP, after adjusting temporary periodic fluctuations in government expenditure and GDP. The results of his empirical analysis demonstrated that the fiscal management of the U.S. government during the sample period (1916 - 95) satisfied the intertemporal budget constraint (in other words, if the ratio of outstanding public debt to GDP rises, the government improves the primary balance into a surplus). Furthermore, Ihori et al. (2001) utilized Bohn (1998)'s method to examine the sustainability of the finance of the Japanese central government (general account). However, the results of their analysis did not support sustainability of the Japanese government's fiscal management during the sample period (1956 - 98).

Now, let us consider Broda and Weinstein (2005) and related literature. Broda and Weinstein (2005) demonstrated the ratio of tax revenue to GDP that enables sustainability of Japanese government finance, via simulation analysis. The process was as follows. 1) If the ratio of outstanding government debt¹³ to GDP in the target period can return to the initial level (with no economic collapse at the starting point), government finance was defined as sustainable. 2) Next, the ratio of tax revenue to GDP (fixed throughout the period targeted by the analysis) required to satisfy the above condition

¹¹ Hamilton and Flavin (1986) used these lag variables in order to eliminate serial correlation of error terms.

¹² This is a test that utilizes the following facts: if outstanding public bonds cannot accumulate indefinitely, under the condition of the discounted present value of the indefinitely rolled-over outstanding government debt converging to zero, outstanding public bonds are mean-reverting and stationary. Therefore, if the government's annual expenditure and annual revenue have unit roots, the government's annual expenditure and annual revenue are cointegrated.

¹³ The net outstanding debt of general government (consisting of central government, local governments, and social security funds) is adopted as outstanding government debt.

was derived from the government's intertemporal budget constraint. 3) Subsequently, they simulated the ratio of government revenue to GDP that enables fiscal sustainability under the given respective socioeconomic variables¹⁴ (period of 2000 - 2100). In Broda and Weinstein (2005) and its related analysis, the expansion of the aging population in Japan has a major impact on the analysis results. The results of their analysis showed that even in a relatively pessimistic simulation scenario, the required ratio of tax revenue to GDP remains at the level of typical EU nations (and at the U.S. level in a relatively optimistic simulation). In other words, their analysis results suggest that the Japanese economy and government finance will not collapse if Japan's tax rate is raised from the current status to a reasonable level, as Japan's ratio of tax revenue to GDP is considerably low when compared with the average of developed nations worldwide. Furthermore, Doi et al. $(2011)^{15}$ updated Broda and Weinstein (2005)'s analysis. They demonstrated that it is necessary to raise the ratio of government revenue to GDP from the current 30% to 40 - 47% in order to make Japanese government finance sustainable. Moreover, Doi et al. (2011), with consideration for factors such as future social security payment obligation, set a more severe initial value of outstanding government debt than Broda and Weinstein (2005).

In addition, Ueda and Sugiura (2011), following the method of EC (2006), estimated the size of the additional primary balance (referred to as the "Sustainability Gap") required in order to achieve the desirable ratio of outstanding public debt to GDP in the target period in Japan from the government's intertemporal budget constraint, under the various given socioeconomic variables, similarly to Broda and Weinstein (2005). Their analysis demonstrated that additional improvement of the primary balance of 8.2% (to GDP) is necessary in order to set the ratio of outstanding public debt (including local government debt) to GDP at 60% in 2050. Furthermore, Hoshi and Ito (2014) simulated the dynamics of Japan's outstanding government debt and private financial assets by assigning various socioeconomic variables exogenously¹⁶to transition equa-

¹⁴ The concrete given variables are as follows: during the simulation period, the growth rate of the nominal money supply, fiscal transfer to the elderly, government expenditure other than the cost of paying interest on public bonds and fiscal transfer to the elderly, demographic structure, the interest rate on public bonds, and the rate of economic growth; also, outstanding public bonds at the starting point.

¹⁵ Doi et al. (2011) also conducted an analysis that expanded upon Bohn (1998) in order to consider the changes in the government's fiscal management regime, using a Markov switching model. The results of their analysis showed that Japan's government finance is not sustainable. Furthermore, Ito et al. (2011) also used a Markov switching model to verify the status of changes in government fiscal management regimes in Japan, the U.S., and the U.K. from the 1880s to 2000s. From their analysis results, it was demonstrated that Japan's government finance is not sustainable, in symmetry to the other two countries.

¹⁶ Hoshi and Ito (2014) adopted Doi et al. (2011)'s calculated value as the initial value of outstanding government debt.

tions of outstanding government debt and private financial assets. The results of their analysis demonstrated that current government fiscal management is not sustainable, as outstanding government debt will exceed private financial assets in 2024 even in a relatively optimistic scenario of 2% GDP growth rate, and also that raising the ratio of government revenue to GDP up to 43 - 50% is required for sustainable fiscal management.

Finally, I discuss analysis that utilizes a Dynamic General Equilibrium model (DGE model). A major shortcoming of simulation analysis that assigns various socioeconomic variables as exogenous variables, as described above, is that it is not possible to observe the influence of the government's fiscal management on various socioeconomic variables and on government finance itself. Accordingly, in order to respond to this problem, a DGE model, which dynamically describes the general equilibrium, has been used. This model considers optimization behaviors of respective economic agents, based on the micro-foundation. The following prior studies can be cited as analyses that have utilized this model in connection to the sustainability of Japanese government finance: Kato (2002), Ihori et al. (2006), Shimazawa and Oguro (2010), Sugawara and Hosono (2011), and others. Kato (2002) analyzed the impact of the deficit in government finance, public capital, and the tax burden of public pension policy on the capital accumulation and the welfare of Japanese citizens. From his analysis, it was shown that through cuts in public investment and the consequent reduction of the future fiscal deficit, the lifetime utility of each generation is most likely to rise in the case where the ratio of outstanding public debt (including local government debt) to GDP converges to 90% from 2045 onward (in the case where this ratio is lowest). Ihori et al. (2006) demonstrated that in a base case where the growth rate of technology, the convergence value of the ratio of outstanding public debt (including local government debt) to GDP, and the convergence value of the ratio of the social security fund amount to GDP are assumed to be zero, 176%, and 42.1%, respectively, the ratio of tax burden to GDP will rise significantly to 35.93% (2002 actual value = 15.62%), and the ratio of social security burden to GDP to 23.27% (2002 actual value = 9.69%), by 2050. Using the open economy model of 16 countries and regions, Shimazawa and Oguro (2010) analyzed the effects of policies that accept immigration to Japan and raise the consumption tax. Their analysis demonstrated that the ratio of outstanding government $debt^{17}$ to GDP would reach 699.42% (by 2050) in a case where 150,000 immigrants are accepted per year from 2006 and the consumption tax rate is not increased, whereas the the ratio of outstanding government

¹⁷ The gross outstanding debt of general government (consisting of central government, local governments, and social security funds) is adopted as outstanding government debt.

debt to GDP could be suppressed to 246.63% (by 2050) in a case where acceptance of immigration is not implemented and the consumption tax rate is raised to 30% from 2015. Sakuragawa and Hosono (2011) conducted a simulation analysis using a Dynamic Stochastic General Equilibrium Model (DSGE model) that can explain the relationship between the interest rate on public bonds and the rate of economic growth. The results of their analysis demonstrated that if the Japanese government's current situation of primary deficit is not rectified, the ratio of outstanding government debt to GDP will reach 1,184% (by 2109), with a probability of almost 100%, in a base case where the rate of economic growth is 1%. On the other hand, it was also demonstrated that if the government achieves a primary surplus after 10 years, and reforms fiscal management to achieve a ratio of primary surplus to GDP of 2.2% (if using consumption tax to achieve this, raising the tax rate to 21%) after 20 years, the ratio of outstanding government debt to GDP will stabilize at a level of approximately 230% by 2109, with a probability of over 90%.

2.1.2 Monetization of government debt

First, Sargent (1999) and Sargent and Wallace (1981) are discussed. Sargent (1999) and Sargent and Wallace (1981) explained the basic concept of monetization of government debt. They explained that it is important to consider government fiscal policy in examining the role of monetary policy. An outline of their argument is as follows. 1) When the government budget constraint is considered, it is fundamental that government annual expenditure (including the payment of interest on public bonds) is covered firstly by tax revenue, and secondly by revenue from public bonds. However, the residual that cannot be covered by these two forms of revenue can be met by revenue gained by increasing the money supply, namely "seigniorage." In this way, the monetary policy of the central bank must follow the government's fiscal policy. 2) As a result, the rate of inflation is determined at the point of balance between fiscal deficit and seigniorage. 3) Furthermore, if outstanding issued interest-bearing government bonds exceed the limit allowed by the economy, as a result of the government's continuation of deficit financing, the central bank is inevitably forced to monetize government debt. 4) From the above, it is clear that the central bank cannot sufficiently control inflation if the government's fiscal policy is sloppy: a disciplined fiscal policy is a prerequisite for the implementation of disciplined monetary policy.

Next, the work of Krichel et al. (1996) is discussed. Krichel et al. (1996) analyzed the effects of the relationship between government fiscal policy and the monetary policy of

the central bank on the economy under multiple scenarios, including a scenario in which the central bank responds via the above-described monetization of government debt. Their analysis utilized a dynamic game model with the following features: one central bank and two governments (countries) exist as players; cooperative or noncooperative actions are taken between the said players; and domestic goods and imported goods exist as commodities consumed by households. Additionally, a numerical simulation based on this model showed that under a scenario in which the central bank does not carry out monetization of government debt, or the central bank commits to inflation targeting, it is possible to control inflation and outstanding government debt more effectively in comparison to a scenario in which the central bank responds via the monetization of government debt.

Next, I review the work of Detken (1999), which is an analysis that presents the advantages of monetization of government debt. Detken (1999) used an OLG model to explain how intergenerational wealth redistribution changes in two respective cases: a case in which the government relies on revenue from the issuance of public bonds as a means of annual revenue, and a case in which the government relies on seigniorage revenue via the monetization of government debt by the central bank. His analysis demonstrated that redistribution of wealth from future generations to the current generation is carried out in the former case, and from the current generation to future generations in the latter case.

Next, let us consider the work of Tanner and Devereux (1993), which verified the monetization of government debt. They conducted an empirical analysis on the relationship between government fiscal deficit and real money demand in the U.S. (with the data from the 1950-1990 period). They demonstrated a positive correlation between real money holdings and government debt. However, the primary cause of this was not related to money supply, but originated on the demand side. That is to say, a situation in which the Federal Reserve monetizes government debt was not permitted.

Finally, let me refer to Broda and Weinstein (2005), which I introduced in Section 2.1.1. They also inspected the impact of monetization of Japanese government debt on the sustainability of government finance (the framework of their analysis is as previously described). They measured the effect of the BOJ monetizing 50% of the initial outstanding government debt during the first five years of the simulated period (with the ratio of money supply to GDP increasing by 30%). Consequently, they demonstrated that the monetization of government debt is not particularly effective in terms of enabling sustainable finance but would only decrease the ratio of government revenue to GDP that allows sustainable government fiscal management, by a mere few tenths of a

percentage point. Furthermore, they explained the reason for this result as follows. The main cause of the government's intertemporal budget constraint becoming stricter is not the current outstanding government debt, which has been reduced by the recent increase in inflation, but the future debt, which is not reduced by this.

2.1.3 Dynamic general equilibrium simulation analysis using an OLG model

In this section, I explain the DCGE-OLG model, the analysis method used in this study. This model was first used by Auerbach and Kotlikoff (1983, 1987), which analyzed the intertemporal influences of various fiscal policies, including tax policy, on the economy. The characteristics of the model are as follows. 1) The respective economic agents possess perfect foresight in relation to various socioeconomic variables. 2) Owing to 1), the respective economic agents utilize all currently available information and form expectations in a forward-looking manner (i.e., a forward-looking model). 3) In 2), the respective economic agents carry out optimization behavior, based on a micro-foundation.

Furthermore, this analysis method has the following advantages: 1) As stated in Section 2.1.1, it differs from simulation analysis that assigns various socioeconomic variables as exogenous variables and can consider the reactions of the respective economic agents to changes in exogenous variables such as fiscal policy. 2) Owing to 1), it is possible to observe the repeated effects of multiple variables endogenously determined within the model on the government sector. 3) As it is general equilibrium analysis, it is possible to observe influences between economic agents and changes in society as a whole. 4) Since it is a dynamic model, it is possible to observe the transition process of society. 5) As it is a numerical simulation analysis, it is possible to construct a model that conforms to actual social structure, in accordance with the analysis objective. 6) As it is an OLG model, it is possible to observe the dinancial burdens of each generation in detail.

Owing to the advantages described above, this analysis method has been utilized in various prior works until now. Accordingly, I review some of these studies. First, a large number of studies have analyzed the influence of public-pension-system reform on the economy and government finance (savings rate, welfare of citizens, etc.), in the context of advancing population aging. For example, Auerbach et al. (1989) targeted the U.S., Japan, Germany, and Sweden; Iwamoto et al. (1993) focused on Japan; Hviding and Mérette (1998) targeted the U.S., Japan, France, Canada, Italy, and the U.K.; Kato (1998) focused on Japan; and Miles (1999) targeted the U.K. and Europe. In general, the results of these studies demonstrated that population aging has a significant negative impact on the economy and government finance. On the other hand, using an OLG model that considers endogenous growth via the accumulation of human capital, works such as Fougère and Mérette (1999) and Sadahiro and Shimazawa (2002) showed that the negative impact of population decline was likely offset by the positive effect of human-capital accumulation on economic growth. Note that Fougère and Mérette (1999) targeted the U. S., Japan, France, Canada, Italy, and the U.K.

In addition, Supan et al. (2001, 2005) analyzed the impact of population aging and reform of public pension system on interregional capital flow using a multi-country OLG model. Supan et al. (2001) targeted five regions (Germany, the U.S., Japan, the remaining EU nations, and the remaining OECD nations), while Supan et al. (2005) targeted seven regions (Germany, France, Italy, the remaining EU nations, the U.S. and Canada, the remaining OECD nations, and the rest of the world).

2.2 Aim of this study

In Sections 1 and 2.1, the following facts were clarified in relation to the Japanese economy and government finance. 1) When the economy is viewed as a whole, the Japanese economy is currently sound relative to various other countries in terms of both flow and stock. 2) However, the public sector, which is part of the overall economy, is unsound in terms of both flow and stock. 3) Population aging, which is anticipated to increase in the future, will very likely have a significant negative impact on the Japanese economy and government finance. 4) Many existing studies suggest that Japanese government finance is not sustainable. 5) Furthermore, at the very least, Japan must raise the national burden to the same level as typical European nations, or reduce government annual expenditure, in order to avoid the collapse of Japanese government finance and the economy.

With regards to item 5) above, to the best of the author's knowledge, existing studies are limited to those that analyze the effects of raising various tax rates, cutting public expenditure, lowering the pension benefit level, and partial monetization of government debt. Accordingly, I aim to analyze the effects of DUPB by the Japanese central bank (BOJ), as another policy to prevent the collapse of Japanese government finance and economy while also maintaining the current level of government expenditure and public pension system. The reasons for examining this policy are as follows. 1) Article 5 of the Public Finance Act actually lays down the principle of market absorption of JGBs in order to avoid the occurrence of extreme inflation through an increase in the money supply caused by direct underwriting of JGBs by the BOJ. However, pragmatically, due to the policy of monetary easing since 1998, the BOJ is continuing to purchase JGBs from the market in large amounts (Table 1). 2) The BOJ obtains the central bank's seigniorage,¹⁸ namely the difference between interest revenue on interest-bearing financial assets (of which JGBs account for the vast majority) and the cost of administrating issued currency (liabilities, i.e., BOJ banknotes). Moreover, the BOJ pays the majority of this seigniorage to the national treasury (Table 1), according to the provisions of Article 53 of the Bank of Japan Act. Ultimately, the BOJ's seigniorage becomes annual revenue for the government.¹⁹ 3) As shown in points 1) and 2), DUPB by the BOJ has both positive and negative effects on Japan's economic mechanism. Thus, quantitative measurement of these effects on both sides is extremely meaningful in order to consider whether such a policy can save the Japanese economy and government finance from failure and how it influences the welfare of Japanese citizens. On the basis of the ideas described above, I chose to use a DCGE-OLG model to quantitatively measure the effects of DUPB by the BOJ.

3. Model

The model of this study is a version of the DCGE-OLG model presented by Auerbach and Kotlikoff (1983, 1987) that incorporates the Japanese public pension system. In addition, in order to realize the aim of this study as discussed in Section 2.2, this study's model is one that considers a situation in which the BOJ, Japan's central bank, directly underwrites public bonds issued in order to finance the government's financial deficit of each fiscal year, and also a situation in which the BOJ does not directly underwrite them.

The basic settings of this study's model are as follows: 1) There is a representative household for each generation, i.e., households in each generation are identical. Preferences are the same for all households in all generations. Moreover, each household maximizes its expected life-cycle utility, under the given wage rate and interest rate determined within each respective market, and the government's fiscal system and pension system. 2) Similarly to representative households, a representative firm carries out profit maximization behavior under the given wage rate and interest rate. 3) The government carries out annual expenditure using tax revenue, revenue from the issu-

¹⁸ For the definition of seigniorage, see Neumann (1992), Baltensperger and Jordan (1997, 1998), and Schobert (2000). In regards to the actual magnitude of seigniorage, see Neumann (1992), Reserve Bank of Australia (1997), Schobert (2000), and Oguri (2006).

¹⁹ For an explanation of the central bank's seigniorage and the actual situation in Japan, see Oguri (2006).

ance of public bonds, and the payment of interest revenue on public bonds by the central bank as fiscal resources. 4) The pension sector pays pension benefits using pension funds, income from the administration of pension funds, and revenue from pension contributions as fiscal resources. 5) The central bank either directly underwrites public bonds or does not do so. In the former case, the central bank pays the interest revenue on public bonds to the government. 6) Each respective market is in perfect competition. 7) This study's model adopts the closed economy model, based on the research aim, and does not explicitly handle bequests for the purpose of simplification. Accordingly, I describe the model used in this study below, with reference to the descriptions by Auerbach and Kotlikoff (1987), Sadahiro and Shimazawa (2002), and Sadahiro and Shimazawa (2010).

3.1 Household sector

Respective households exist in each generation, and this study setts representative households throughout all generations as follows. 1) The preferences of representative households are the same throughout all generations. 2) Representative households are considered to appear simultaneously in the model and on the labor market at the age of 21 (the 1st period), retire at the age of 64 (the 44th period), and decease at the age of 105 (the 85th period)²⁰; each household (individual) inelastically supplies one unit of labor from the 1st period to the 44th period. 3) Representative households possess perfect foresight in relation to various socioeconomic variables. 4) Representative households form rational expectations in a forward-looking manner, under the conditions of 3). 5) The utility function of representative households (individuals) possesses constant relative risk aversion, and is additive and separable over time.

Under the above assumptions, firstly, the life-cycle utility function of representative households is specified as follows:

$$U^{i} = \sum_{j=1}^{d} \left(\frac{1}{1+\rho}\right)^{j-1} \frac{1}{1-\frac{1}{\gamma}} u_{ij}^{1-\frac{1}{\gamma}} = \sum_{j=1}^{d} \left(\frac{1}{1+\rho}\right)^{j-1} \frac{1}{1-\frac{1}{\gamma}} c_{ij}^{1-\frac{1}{\gamma}}, \tag{1}$$

where *i* denotes the generation, and *j* denotes the life period, i.e., age (20 + j years old) at the *j* th period). Furthermore, u_{ij} represents the utility of each period (at each age)

²⁰ The age of death is adjusted to the population projection data used in the simulation. Details of this data are explained in Section 4.1.

of each generation, c_{ij} the consumption of the *j*th period of generation *i*, ρ the rate of time preference, γ the intertemporal elasticity of substitution, and *d* the assumed final period of each household (here, d = 85).

Next, the budget constraint equation of generation i in year t is as follows :

$$(1 - RD2_{t+1})a_{ij+1} = [1 + (1 - \tau r_t)r_t(1 - RD2_t)]a_{ij-1} + (1 - rp_{it})(1 - \tau w_t)w_te_j - (1 + \tau c_t)c_{ij} + (1 - \tau p_t)p_{ij},$$
(2)

where a_{ij} represents the assets at the end of the *j*th period, r_t the interest rate in year t, w_t the wage rate, e_j the wage profile in the *j*th period (j + 20 years old), p_{ij} the amount of pension benefit in the *j*th period, τr_t the interest income tax rate in year t, τw_t the labor income tax rate, rp_{it} the public pension contribution rate in the *j*th period, τc_t the consumption-based tax rate, τp_t the pension income tax rate, and $RD2_t$ the ratio of outstanding public debt held by the central bank (from the base year) to outstanding national assets $(RD2_t = 0$ in the scenario in which the central bank does not directly underwrite public bonds).²¹ Furthermore, the relationship between year, generation and age (each period of life) is as follows: t = i + j - 1.

In addition, the above wage profile is specified as a function of age, as follows.

$$e_{i} = \phi_{0} + \phi_{1}(20+j) + \phi_{2}(20+j)^{2}$$
(3)

Moreover, the amount of pension benefit p_{ij} of generation *i* in the *j*th period consists of the fixed amount portion and the remuneration-based portion as follows:

$$p_{ij} = pf_{ij} + pr_{ij} = pf_{ij} + \theta_t PVAW_{ij}, \qquad (4)$$

where pf_{ij} represents the amount of the fixed amount portion in the *j*th period, pr_{ij} the amount of the remuneration-based portion in the *j*th period, $PVAW_{ij}$ the average annual labor income of working period converted into the value at the time of pension receipt using the interest rate, and θ_t the ratio used to calculate the amount of the remuneration-based portion from $PVAW_{ij}$ in year *t*.

Furthermore, the intertemporal budget constraint of generation i from Equation (2) is obtained as follows:

²¹ Such direct underwriting of public bonds by the central bank is assumed to have an equal ratio of impact both on household assets and on public pension assets (see Section 3.4).

$$\sum_{j=1}^{d} (1+\tau c_t) c_{ij} DF_{ij} = \sum_{j=1}^{d} (1-rp_{it}) (1-\tau w_t) w_t e_j DF_{ij} + \sum_{j=1}^{d} (1-\tau p_t) p_{ij} DF_{ij}, \quad (5)$$

where DF_{ij} is a discount factor for converting the value of generation *i* in the *j*th period into the value at the time of the 1st life period. This discount factor is as follows.

$$DF_{ij} = \begin{cases} \frac{1}{\prod_{m=2}^{j} [1 + (1 - \tau r_{i+m-1})r_{i+m-1}(1 - RD2_{i+m-1})]} & \text{if } j \ge 2\\ 1 & \text{if } j = 1 \end{cases}$$
(6)

Households maximize the life-cycle utility [Equation (1)] subject to the intertemporal budget constraint [Equation (5)]. This utility maximization yields the following Eular equation on consumption per period.

$$c_{ij} = \left[\frac{1 + (1 - \tau r_t)r_t(1 - RD2_t)}{1 + \rho}\right]^{\gamma} \left(\frac{1 + \tau c_{t-1}}{1 + \tau c_t}\right)^{\gamma} c_{ij-1}$$
(7)

3.2 Firm sector

One representative firm exists in the private sector, and this study's model sets this representative firm as follows. 1) The productive structure of this firm is expressed by the Cobb-Douglas production function with constant return to scale. 2) This firm uses the capital and labor supplied by households as production factors, where the latter is measured by efficiency unit. 3) Its products are used both as consumer goods and as investment goods. 4) The technological progress is Harrod neutral and its rate (per year) is exogenously constant.

Under the above assumptions, the production function of the representative firm is specified as follows:

$$Y_t = AK_t^{\alpha} L_t^{1-\alpha} = AK_t^{\alpha} [(1+\lambda)^t L_t]^{1-\alpha}, \qquad (8)$$

where Y_t represents output in year t, K_t the physical capital stock, and L_t the effective labor. Furthermore, A represents the scale parameter, α the capital share in production, and λ the technological progress rate.

Additionally, the physical capital stock K_t follows the transition equation below.

$$K_t = I_t + (1 - \delta)K_{t-1}$$
(9)

In this equation, I_t represents the gross private investment in year t, and δ represents the depreciation rate of physical capital.

Moreover, under the above configuration, profit maximization behavior by the firm generates the following two equations that determine optimal factor demands.

$$r_t = \alpha A \left[\frac{\kappa_t}{(1+\lambda)^t L_t} \right]^{-(1-\alpha)} - \delta = \alpha A k_t^{-(1-\alpha)} - \delta$$
(10)

$$w_t = (1-\alpha)A(1+\lambda)^t \left[\frac{K_t}{(1+\lambda)^t L_t}\right]^{\alpha} = (1-\alpha)A(1+\lambda)^t k_t^{\alpha}$$
(11)

In these equations, k_t represents the physical capital stock per unit of effective labor.

3.3 Government sector

This study's model specifies the central government, local governments, and social security funds (excluding the pension sector described in Section 3.4), as the government, and sets the government factors as follows. 1) The government has taxation, the issuance of public bonds, and the payment of interest revenue that public bonds held by the central bank bear, as means of annual revenue. 2) The items of taxation are labor income tax, interest income tax, pension income tax, and consumption-based tax. 3) The government maintains the amount of annual expenditure in the base year excluding the amount of annual expenditure for the elderly (per member of the population over age 21) and the amount of annual expenditure is hereinafter referred to as "GAE", and the latter expenditure as "EAE". 4) Additionally, the government subsidizes part of a fixed payment portion to the pension sector every year.

Under the above assumptions, firstly, the government's total tax revenue in year t is expressed as follows:

$$T_{t} = \sum_{j=1}^{d} GEN_{tj} \left[\tau w_{t} w_{t} e_{j} + \tau r_{t} r_{t} (1 - RD2_{t}) + \tau c_{t} c_{ij} + \tau p_{t} p_{ij} \right],$$
(12)

where T_t represents the government's total tax revenue in year t and GEN_{tj} represents generation i's (i = t + 1 - j) population in the *j*th period (20 + j years old).

Next, the government's total annual revenue in year t is expressed as follows:

$$TR_t = T_t + r_t DEBT2_{t-1} , (13)$$

where TR_t represents the government's total annual revenue in year t, and $DEBT2_{t-1}$ represents outstanding public debt held by the central bank in year t - 1. In other words, the second term on the right-hand side of Equation (13) is the payment of the interest revenue on public bonds to the government by the central bank (i.e., this interst revenue is the central bank's seniorage). However, this is zero in the scenario in which the central bank does not directly underwrite public bonds.

Next, the government's total annual expenditure in year t is expressed as follows:

$$G_t = NG_t + PFTR_t = \left[\sum_{j=1}^{44} GEN_{tj}g_{base}^{noold} + \sum_{j=45}^{d} GEN_{tj}g_{base}^{old}\right] + sr_t \sum_{j=45}^{d} GEN_{tj}pf_{ij}, \quad (14)$$

where G_t represents the government's total annual expenditure in year t, NG_t the amount of annual expenditure excluding fiscal transfer to public pensions, $PFTR_t$ the fiscal transfer related to the fixed payment portion of public pensions, and sr_t the national subsidy rate related to the fixed payment portion of public pensions. g_{base}^{noold} represents the amount of GAE, and g_{base}^{old} represents the amount of EAE. Additionally, annual expenditure per member of the population is fixed at the base year value. From the above, the government's budget constraint equation (transition equation) in year t is as follows:

$$TDEBT_{t} = (1+r_{t})TDEBT_{t-1} + (G_{t} - TR_{t}),$$
(15)

where $TDEBT_t$ represents the total outstanding public debt at the end of year t. Furthermore, the amount of public bonds issued in year t, the fiscal balance, and primary balance are expressed as follows.

$$BOND_t = r_t T D E B T_{t-1} + (G_t - T R_t)$$
(16)

$$FB_t = TR_t - G_t - r_t TDEBT_{t-1} \tag{17}$$

$$PB_t = TR_t - G_t \tag{18}$$

In these equations, $BOND_t$ represents the amount of public bonds issued in year t, FB_t the fiscal balance, and PB_t the primary balance.

3.4 Public pension sector

In order to recreate Japan's actual public pension system, this study's model utilizes a pension system adopting a modified funding method. The sources of annual revenue for this system are public pension contribution income collected from the labor income of the working generations, pension funds, the interest revenue generated from pension funds, and fiscal transfer related to the fixed payment portion from the government. Furthermore, the pension payment consists of a fixed payment portion and a remuneration-based portion. Under these assumptions, the budget constraint equation (transition equation) of the pension sector is as follows.

$$(1 - RD2_{t+1})PFUND_{t}$$

$$= (1 + r_{t})(1 - RD2_{t})PFUND_{t-1} + \sum_{j=1}^{44} GEN_{tj}\tau p_{it}w_{t}e_{j}$$

$$+ sr_{t} \sum_{j=45}^{d} GEN_{tj}pf_{ij} - \sum_{j=45}^{d} GEN_{tj}p_{ij}$$
(19)

In this equation, $PFUND_t$ represents the assets held by the pension sector at the end of year t. The first term on the right-hand side of Equation (19) represents the interest revenue on held assets, the second term public pension contribution revenue, the third term the fiscal transfer related to the fixed payment portion from the government, and the fourth term the pension payment.

3.5 Central bank sector

I prepared two scenarios in relation to the absorption of public bonds after the year following the base year (2012) of the simulation. In the first scenario, public bonds are absorbed by the market, as has been the case until now. In the second scenario, public bonds are directly underwritten by the central bank (BOJ). In order to describe these two scenarios, I formulated the ratio of outstanding public debt to outstanding national assets as shown below. Additionally, regarding the payment of interest revenue on public bonds to the government (the central bank's seniorage) by the central bank, see Equation (13).

$$TDEBT_t = DEBT1_t + DEBT2_t \tag{20}$$

$$RD_t = \frac{TDEBT_t}{TFA_t} \tag{21}$$

$$RD1_t = \frac{DEBT1_t}{TFA_t} \tag{22}$$

$$RD2_t = \frac{DEBT2_t}{TFA_t}$$
(23)

In these equations, $DEBT1_t$ represents the outstanding public debt held by the private sector (namely, households) at the end of year t, $DEBT2_t$ the outstanding public debt held by the central bank (BOJ), TFA_t the outstanding national assets, RD_t the ratio of total outstanding public debt to outstanding national assets, and $RD1_t$ the ratio of outstanding public debt held by the private sector.

Furthermore, for the purpose of simplification, this study's model does not explicitly handle money supply. Instead, the effect on the economy of DUPB by the central bank, as shown in Equation (20), is considered due to the fact that the amount directly underwritten by the BOJ (within outstanding public bonds) does not become household assets.

3.6 Aggregation

Under the settings as explained up to Section 3.5, the optimal consumption stream $\{c_{ij}\}$ and the optimal asset stream $\{a_{ij}\}$ of the generation *i* household, the capital stock demand stream $\{K_t\}$, and effective labor demand stream $\{L_t\}$ are derived. When these are utilized, total consumption in year *t*, C_t , and total assets held by households at the end of year *t*, PA_t , are expressed as follows.

$$C_t = \sum_{j=1}^d GEN_{tj}c_{ij} \tag{24}$$

$$PA_{t} = \sum_{j=1}^{d} GEN_{tj}a_{ij} \left(1 - RD2_{t}\right)$$
(25)

Furthermore, the total effective labor supply in year t, L_t^s , is expressed as follows.

$$L_t^s = \sum_{j=1}^d GEN_{tj} e_j \tag{26}$$

3.7 Market equilibrium

The following market-equilibrium conditions must hold in order to close the model structure. Firstly, the equilibrium conditions of the production factor markets, in other words the effective labor market and the capital market,²² are as follows.

$$L_t^s = L_t$$

$$PA_t + PFUND_t = K_t + TDEBT_t = K_t + (DEBT1_t + DEBT2_t)$$
(27)
(28)

Finally, the equilibrium condition of the goods market is as follows.

$$Y_t = C_t + I_t + NG_t \tag{29}$$

4. Parameters (estimation and calibration) and data

This section gives an overview of how to set the parameter values and the sources of the data, which are used in the simulation. In addition, the details of these are provided in the Appendix. Furthermore, as this study is an analysis made with consideration for the government's fiscal system, it should be noted that the year units used in this study are essentially fiscal years, not calendar years.²³

4.1 Parameters (estimation and calibration)

²² Fundamentally, $TFA_t = PA_t + PFUND_t$. However, if $TDEBT_t < 0$, then $TFA_t = PA_t + PFUND_t + (-TDEBT_t)$.

²³ However, in cases where fiscal year data cannot be utilized or cases where use of calendar year data is considered to be appropriate, I used calendar year data in substitution for fiscal year data, for the purpose of expedience.

First, the parameter values are explained. The parameter values used in this study can be categorized into those that cite values used in prior studies and those that are estimated or calibrated from the data in this study. The parameter and their values used in this study are shown in Table 3, and an overview of how to set their values is described below.

Parameter		Value
Utility function [see Equation (1)]		
Time preference rate	ρ	0.010
Intertemporal elasticity of substitution	Y	2.00
Wage profile function [see Equation (3)]		
Constant term	φ ₀	5.436
Coefficient of first-degree term	φ ₁	0.099
Coefficient of second-degree term	φ2	-0.001
Production function [see Equations (8) and (9)]		
Scale parameter	Α	0.765
Technology progress rate	λ	0.013
Capital share in production	α	0.300
Depreciation rate of physical capital	δ	0.056
Tax policy parameters [see Equation (2)]		
Labor income tax rate (%)	τw	11.5
Interest income tax rate (%)	т <i>г</i>	15.4
Consumption-based tax rate (%)	т с	9.6 - 13.1
Pension income tax rate (%)	тр	11.5
Pension policy parameters [see Equations (2), (4), and (14)]		
Public contribution rate (%)	rp	16.6 - 18.3
Rate to annual average labor income: for remuneration-based pensi	iθ	0.233 - 0.313
National treasury subsidy rate for basic pension benefits	sr	0.500

Table 3. Parameter Values

4.1.1 Household sector

First, the parameter values of the life-cycle utility function of the representative household are cited from prior studies using a DCGE-OLG model, as introduced in Section 2. In addition, the parameters of the wage profile function[Equation (3)] are estimated using the model of Mincer (1974).

4.1.2 Firm sector

The capital-share value (base year 2012) in the production function [Equation (8)] was calculated using data from the National Accounts (NA) by Cabinet Office. Furthermore,

the depreciation-rate value (mean value of 2000 - 12) of physical capital was calculated using data from the "Gross Capital Stock of Private Enterprises" (Cabinet Office). Additionally, the base year (2012) value of physical capital stock was calculated from the NA's outstanding financial assets and financial liabilities.

Next, the scale parameter is explained. This value (base year 2012) was calibrated using the following data: the parameters calculated thus far, physical capital stock, total effective labor measured in efficiency units, which was calculated using data from the "Population Projections for Japan" (PPJ²⁴) and the wage profile function [Equation (3)], and Gross National Income (GNI) from the NA.

Finally, the value of technological progress rate was estimated via a method using the Solow residual,²⁵ following Kamada and Masuda (2001) and Miyazawa (2008).

4.1.3 Government sector

First, the tax rate values are as follows. 1) The values (base fiscal year 2012) of the labor income tax rate and interest tax rate were calculated from the NA data. Furthermore, the value of the pension income tax rate was set to be the same as that of the labor income tax rate. 2) The value (mean value for the fiscal years 2010 - 12) of consumption-based tax rate was calculated using "Ministry of Finance Statistics Monthly" (Ministry of Finance) and the NA data. In addition, the values of consumption-based tax rates for the respective fiscal years targeted by the simulation were set to be consistent with the government's plan to revise the consumption tax rate.

Next, the value of subsidy rate related to the fixed payment portion of public pensions is the value under the system implemented from fiscal year 2009.

4.1.4 Public pension sector

First, the values of public pension contribution rates on labor income are consistent with the default values of Japan's Employee's Pension Insurance and the values planned to be raised. Next, the values of ratios used to calculate the remuneration-based portion of pension benefits are those used for Employee's Pension Insurance. The ratio value for the generations born in and before 1944 is assumed to be the same as that of the generation born in 1945.

²⁴ I used the data projected in 2012 by the National Institution of Population and Social Security Research.

 $^{^{25}}$ See Solow (1957) for the Solow residual.

4.2 Data

This section explains the data used in this study. In addition, note that the money amount data were deflated by the GDP deflator (2005 = 100) from the NA.

4.2.1 Household sector

First, the initial values of assets held by the respective generations who are aged 22 or older at the simulation base year (hereinafter, "transition generations"), namely the assets as of the end of fiscal year 2011, were calculated from the following data: the outstanding financial assets of Japan as a whole (from the NA), the population of each age group (from the PPJ), and the amount of savings and liabilities per household (for each age category) stated in the "Annual Report on the Family Income and Expenditure Survey" (Ministry of Internal Affairs and Communications).

Second, the data related to pension benefits are explained. Firstly, the fixed payment portion in pension benefits is consistent with the default value of the benefit amount of the National Pension (Basic Pension) and the value planned to be lowered. Secondly, the average annual labor income [*PVAI* in Equation (4)] for every transition generation is calculated from the following two factors: 1) labor income in and prior to fiscal year 2011, 2) labor income in and after fiscal year 2012. The latter of these is determined endogenously within the simulation, whereas the former is calculated from the standard labor income (the actual basis for calculating the remuneration-based benefit amount) in fiscal year 2012, in accordance with the number of years worked until fiscal year 2011. This standard labor income is obtained from the "Overview of the Employee's Pension Insurance and National Pension Service" (Ministry of Health, Labour and Welfare).

4.2.2 Population (future population projections)

The population of each age group (combined total of men and women) in the age range of 21 - 105 during the simulation period was obtained from the PPJ. However, the following points should be noted. 1) The setting in which a representative household lives to the age of 105 conforms to the PPJ. 2) The data of the medium-fertility and medium-mortality case are used. 3) The population of each age group in and after 2111 is assumed to be the same as the 2110 values

4.2.3 Firm sector

The initial value of physical capital stock per unit of effective labor, namely the physical capital stock as of the end of fiscal year 2011, is calculated from the following data: the outstanding financial assets amount and liabilities amount of Japan as a whole, the total effective labor calculated using the population of each age group (from the PPJ), and the wage profile function [Equation (3)].

4.2.4 Government sector

The amount of GAE and amount of EAE in the base fiscal year (2012) are calculated using data from the NA and the PPJ.

4.2.5 Total assets, public pension assets, and government sector outstanding debt

The initial values of the total assets of Japan as a whole, public pension assets, and government sector outstanding debt, namely the values of these variables as of the end of fiscal year 2011, were calculated from the outstanding financial assets amount and liabilities amount by sector of economy (from the NA).

5. Simulation

In this section, the simulation scenarios, the contents of the sensitivity analysis, and the results of both the base simulation and the sensitivity analysis are explained.

5.1 Scenarios

I prepared the following two scenarios in order to examine the effects of DUPB by the central bank (BOJ) on the Japanese economy and government finance.

Scenario 1: Scenario in which DUPB is implemented by the BOJ.

In this scenario, the central bank (BOJ) directly underwrites public bonds issued by the government, from fiscal year 2013 onward. For the purpose of simplification, this scenario is hereinafter referred to as the "UWCB scenario."

Scenario 2: Scenario in which DUPB is not implemented by the BOJ. In this scenario, public bonds issued by the government are absorbed by the market in accordance with Article 5 of the Public Finance Act, even after fiscal year 2013, as has been the case until now. For the purpose of simplification, this scenario is hereinafter referred to as the "NOTUWCB scenario."

Furthermore, the following facts should be noted in relation to the simulation²⁶ used in this study. First, the years in the simulation are fiscal years. Moreover, the starting fiscal year of the simulation, in other words the base fiscal year, is set to be fiscal year 2012. Second, transition generations are handled as follows (See Section 4): 1) the actual values of their assets at the end of fiscal year 2011 are provided in the model as initial values; 2) their contributions of the remuneration-based portion of the public pension prior to fiscal year 2011 are set to have been paid, under the same annual amount as the standard labor income of fiscal year 2012; and 3) their behaviors from fiscal year 2012 onward are set within the model. Third, outstanding national financial assets, outstanding public pension assets, and outstanding government debt (the sum of the outstanding debt of central government and that of local governments) at the end of fiscal year 2011 are provided in the model as initial values. Fourth, in order to narrow the focus of this research on the effects of DUPB by the BOJ, I did not incorporate factors other than the predetermined raise of consumption tax rate and revisions of the public pension contribution rates and benefits. Fifth, I am more interested in the transition process than in the steady state of the economy. Furthermore, the main objective of this study is to explore future sustainability of the Japanese economy and government finance. For this purpose, the simulation is set to be terminated if the calculation results arrive at the following two situations: 1) a situation in which sustainability of the economy and government finance is judged to be no longer secured; 2) a situation in which all government debt has been cleared by accelerating the repayment of debt. Sixth, this study used the PPJ data without any processing. This measure was taken to prevent the loss of information held in the PPJ data. As a result, households (individuals) who leave the model before the assumed age of death are supposed to consume the net assets that they possess at the time of leaving.

5.2 Sensitivity analysis

In order to confirm the robustness of this research, I also simulated the cases in which

²⁶ In order to create the simulation program, I referred to OLG model programs released online: including a program created by Hashimoto, K. (http://www2.ipcku.kansai-u.ac.jp/~hkyoji/kenkyu /download.htm), and that created by Oguro, S. and Shimazawa, M. (http://www.nippyo.co.jp /download/535-55664-5/index.php).

the parameter value of the rate of time preference of the life-cycle utility function was changed. This is because a shift in the rate of time preference effectively influences the intertemporal consumption pattern of representative households. The contents of the sensitivity analysis are shown in Table 4.

Case	Time preference rate	Intertemporal elasticity of substitution	Economy and susta	d public finance iinability
	ρ	Y	UWCB	NOTUWCB
Base	0.010	2.000	Yes	No
A1	0.013	2.000	No	No
A2	0.007	2.000	Yes	No

Table 4. Sensitivity Analysis Cases and Sustainability

Note: Yes and No indicate "sustainable" and "not sustainable," respectively.

5.3 Results of simulation and sensitivity analysis5.3.1 Future population structure

The future population structure of Japan is graphed in Figure 5. This figure shows that Japan's total population (aged 21 and over) will decline from the current level of over one hundred million persons to fewer than forty million persons after approximately 100 years. Moreover, the aging ratio, that is, the ratio of the population who are aged 65 and over to the total adult population (aged 21 and over) will rise from the current ratio of approximately 0.300 to a little under 0.500 after approximately 100 years. This signifies that a society will arise in which each worker supports one elderly person. Furthermore, the fact that the speed of the aging of society will be relatively fast until around the mid-2040s, and subsequently become relatively slow, is also demonstrated.



Figure 5. Future Population Structure of Japan

5.3.2 Sustainability

Changes in the ratio of outstanding government debt to GNI for each scenario and for each sensitivity analysis case are shown in Figure 6 (see also Table 4). This figure explains the following facts. 1) The Japanese economy and government finance are sustainable, without collapse, in only the UWCB scenario of the Base case and the UWCB scenario of the A2 case. 2) A rise in the rate of time preference of representative households rapidly engenders the collapse of the economy and government finance.

5.3.3 GNI, total physical capital stock, GNI per capita, and physical capital stock per unit of effective labor

Changes in GNI, total physical capital stock, GNI per capita, and physical capital stock per unit of effective labor are shown in Figures 7 - 10. Figure 7 explains the following facts. 1) In all cases, GNI continues to grow until the aging of population structure reaches its highest level, and subsequently continues to decline after then (see also Figure 5). 2) Furthermore, in the sustainable cases, GNI starts to grow again from around fiscal year 2110. 3) It is clear from a comparison of the two sustainable cases that the A2 case attains higher values of GNI. We can think that the contents of the above items 1) and 2) are generated by the setting of the Harrod-neutral technical progress, advances in the aging of the population, and the setting in which the population after fiscal year 2111 is fixed at the level of fiscal year 2110. Moreover, Figure 7 shows that in the case of economic collapse, GNI rapidly falls when the tendency toward failure of the economy and government finance intensifies. Additionally, we can think that the result described in the above item 3) is produced by a process in which a downward shift in the rate of time preference is followed by a decline in consumption closer to the present, subsequently followed by an increase in accumulation of physical capital stock, finally followed by an increase in production. Furthermore, Figures 8 and 10 show that the changes in total physical capital stock and physical capital stock per unit of effective labor are similar to the changes in GNI.

Next, Figures 9 and 10 explain the continuous rises in GNI per capita and physical capital stock per unit of effective labor in the sustainable cases, due to the decrease in total population and working-age population along with advances in production technology.



Figure 6. Ratio of Outstanding Government Debt to GNI



Figure 7. GNI



Figure 8. Total Physical Capital Stock



Figure 9. GNI (per capita)



Figure 10. Physical Capital Stock (per efficient labor unit)

5.3.4 Base case

Below, I explain the simulation results in detail, focusing on the Base case. Firstly, the actual values of various variables in the economy and government finance and the calculated values of the UWCB scenario in the starting fiscal year of the simulation (base fiscal year) are shown in Table 5. This table says that the calculated value of physical capital stock per unit of effective labor exceeds the actual value. We can think that this result is caused by the following fact: each household with perfect foresight accumulates physical capital stock more rationally in the model than in reality in preparation for future production. In addition, a deviation between the actual value and the calculated value of savings rate to GNI appears in this table. I consider the following reasons for this deviation: 1) larger accumulation of physical capital stock by each household in the model (this is described above), 2) the use of outstanding financial assets to devise the data of physical capital stock, as well as the additional increment of physical capital stock in the model.

Next, Figure 11 shows the changes in outstanding government debt, and Table 6 shows the changes in the ratio of outstanding government debt to outstanding national financial assets and changes in physical capital stock per unit of effective labor. Figure 11 explains the divergence of outstanding government debt in the NOTUWCB scenario. On the other hand, Figure 11 and Table 6 show that outstanding government debt will reach zero in the 2130s in the UWCB scenario. That is to say, the government's continuous fiscal surplus will firstly pay off government debt held by the central bank (BOJ) in the 2120s, and then also pay off initial government debt in the 2130s.

Next, in order to confirm these facts in detail, I show the changes in the primary balance of the government budget, namely the balance that does not include interest payment on outstanding public bonds, and the final balance that includes such payment, in Figure 12 (here, each balance is defined as the ratio to GNI). This figure explains the following facts. 1) In the NOTUWCB scenario, although a primary balance surplus is achieved in itself, a government fiscal deficit in the final balance ultimately diverges, due to the significant burden of interest payment caused by cumulatively increasing outstanding government debt (see also Figure 11). 2) On the other hand, in the UWCB scenario, firstly, the primary balance is brought into surplus at the end of the 2010s. Next, the same is done for the final balance at the mid- 2060s. We can think that this phenomenon in the UWCB scenario is generated by the following process: the central bank (BOJ) directly underwrites public bonds, which creates seigniorage for the BOJ,

then the BOJ pays this seigniorage to the national treasury, leading to improvement of government finance.

Variables	Actual values	Calculated values (UWCB)
Physical capital (million yen) per effective labor unit	1.178	1.294
GNI (billion yen)	439,904	451,573
Savings rate to GNI	0.231	0.461
Ratio of primary balance to GNI	-0.075	-0.079
Ratio of Government debt to TFA	0.526	0.538

Table 5. Economic and Public Finance Variables of 2012 (base fiscal year)

Note: TFA indicates "Total Financial Assets held by Japanese people."



Figure 11. Outstanding Government Debts (Base Case)

Note: DEBTS and DEBT2 indicate "Total outstanding government debts" and "Held by the central

bank (BOJ)," respectively.

		UW	СВ		NOTU	WCB
FY	k	DEBT1 ratio	DEBT2 ratio	DEBTS ratio	k	DEBTS ratio
	(Million yen)	(to TFA)	(to TFA)	(to TFA)	(Million yen)	(to TFA)
2011	1.034	0.547		0.547	1.034	0.547
2012	1.294	0.538	0.000	0.538	1.314	0.534
2020	2.719	0.269	0.238	0.507	3.006	0.504
2030	3.535	0.202	0.292	0.494	4.005	0.515
2040	4.036	0.181	0.314	0.495	4.555	0.544
2050	4.117	0.175	0.336	0.511	4.637	0.587
2060	4.044	0.174	0.346	0.520	4.538	0.628
2070	3.978	0.178	0.346	0.524	4.418	0.671
2080	3.946	0.186	0.335	0.520	4.234	0.720
2090	3.855	0.197	0.309	0.506	3.451	0.797
2100	3.820	0.213	0.265	0.478		
2110	3.519	0.246	0.209	0.455		
2120	4.033	0.242	0.062	0.304		
2130	4.205	0.100	0.000	0.100		

Table 6. Government Debt Ratio and Physical Capital Stock (per effective labor unit)

Notes: (1) "k" indicates physical capital stock per effective labor unit.

(2) DEBT1, DEBT2, and DEBTS indicate "Outstanding government debts held by public sector,"

"Held by the central bank (BOJ)," and "Total," respectively.

(3) TFA indicates "Total Financial Assets held by Japanese people."



Figure 12. PB-ratio and FB-ratio to GNI (Base Case)

Note: PB and FB indicate "Primary balance of government budget" and "Final balance," respectively.

5.3.5 Life-cycle utility level by generation

Finally, this section explains the life-cycle utility level of respective generations in the UWCB scenario of the Base and A1 cases, in which the Japanese economy and government finance are sustainable. In addition, I used an index²⁷ of 1 plus the equivalent variation of each generation's utility level (compared to the base generation's utility level) as the utility-level index of each generation. Moreover, note that the equivalent variation used in this research is excluded from the influence of advances in production technology. In addition, for the purpose of a simplified understanding of the contents of utility level, the utility level index is divided into two segments: working period (ages 21-64) and retirement period (ages 65-85)²⁸. Furthermore, the former base generation is the generation born in fiscal year 2012, and the latter is that born in 1967.

Figure 13 shows the changes in the utility-level index described above. This figure explains the following facts. 1) In both the Base and A1 cases, through the working period and retirement period, the utility level of future generations somewhat exceeds that of the base generation. We can think that this is due to the growth of physical capital stock per unit of effective labor that accompanies the aging of society, as shown in Figure 10, even after excluding the influence of advances in production technology. Additionally, as shown in Figure 9, this growth leads to an increase in GNI per capita. This fact signifies that the policy of DUPB by the BOJ improve the efficiency of added-value distribution in Japan. 2) In comparison to the Base case, the A2 case shows higher utility level in the working period of future generations, and lower utility level in their retirement period. We can think that the result described in the above item 2) is produced by a process in which a downward shift in the rate of time preference is followed by a increase in accumulation of the physical capital stock, finally followed by an increase in production.

²⁷ In other words, this index will be 1 if the utility level of targeted generation is the same as that of the base generation.

²⁸ In order to fully utilize the PPJ data, representative households are set to live from the ages of 21 to 105 (85 periods) in this study. However, when calculating the life-cycle utility level of respective generations, the setting of 85 periods is too long. I therefore set the retirement period to the age range of 65-85.



Figure 13. Equivalent Variation Note: EQVR indicates "Equivalent variation."

6. Concluding remarks

This study elucidated the effects of a policy of DUPB by the central bank using a DCGE-OLG model: this policy has the potential to support the Japanese economy and government finance and to improve the efficiency of added-value distribution in Japan while also maintaining the current level of government expenditure and public pension system. The results of this analysis are summarized in the following four points.

First, failure of the Japanese economy and government finance occurs in the case where public bonds are absorbed by the market. However, in the case where public bonds are directly underwritten by the central bank, the economy and government finance are fundamentally sustainable. This phenomenon is produced by the following process: the central bank (BOJ) directly underwrites public bonds, which creates seigniorage for the BOJ, then the BOJ pays this seigniorage to the national treasury, leading to improvement of government finance.

Second, a downward shift in the rate of time preference of representative households improves the economy and government finance. This phenomenon is produced by the following process: a downward shift in the rate of time preference is followed by a decline in consumption closer to the present, subsequently followed by an increase in accumulation of physical capital stock, finally followed by an increase in production. Third, in the case in which the economy and government finances are sustainable, there will be a continuous rise in GNI per capita and physical capital stock per unit of effective labor due to the decrease in total population and working-age population along with advances in production technology.

Fourth, in the case in which the economy and government finances are sustainable, the utility level of future generations will somewhat exceed that of the base generation. We believe that the growth in physical capital stock per unit of effective labor, which accompanies the aging of society, causes the above state. Furthermore, this growth leads to an increase in GNI per capita. This fact suggests that DUPB by the central bank can improve the efficiency of added-value distribution in Japan

Finally, some remaining issues need to be mentioned. Firstly, the rational-expectation assumption, i.e., that representative households with perfect foresight optimize their behavior, may be too strong. Therefore, it is necessary to conduct further analysis under the adaptive-expectation assumption. Additionally, a comparison of the results of such analysis with those of this study is required. Secondly, while this study's model does not explicitly handle bequests, in the future, a model should be developed in which a bequest element is explicitly incorporated. Thirdly, while this study adopts a closed economy model, this study's model should be expanded into an open-economy model that considers the capital flow between Japan and other countries.

Appendix: Details of Parameters (estimation and calibration) and Data

This Appendix provides detailed explanations how to set the parameter values and the data sources used in the simulation.

A1. Parameters (estimation and calibration)

Note that the money amount data used in parameter calculation and estimation, such data were deflated by the GDP deflator (2005 = 100) from the NA.²⁹

A1.1.1 Household sector

First, Table A1 shows the parameter values of the life-cycle utility function of representative households in prior studies utilizing a DCGE-OLG model introduced in Section 2.

No.	Author	Year	Time preference rate	Intertemporal elasticity of substitution	Technological progress rate : Harrod neutral type
			ρ	γ	λ
1	Auerbach and Kotlikoff	1983	0.020	1.000	0.020
2	Auerbach and Kotlikoff	1987	0.015	0.250	
3	Auerbach et al.	1989	-0.040	0.350	
4	Iwamoto et al.	1993	-0.040	0.300	
5	Hviding and Mérette *	1998	0.003	0.250	0.024
6	Kato	1998	-0.075	0.200	
7	Fougère and Merette *	1999	0.003	0.250	0.024
8	Miles *	1999	0.015	0.750	
9	Supan et al.	2001	0.080	1/3	
10	Kato	2002	-0.035	0.450	
11	Sadahiro and Shimazawa	2002	0.020	1/1.2	
12	Supan et al.	2005	0.011	0.500	0.015
13	Shimazawa and Oguro	2010	0.010	2.000	0.010

Table A1. Parameter Values of Preceding Studies

Note: (1) "*" indicates studies that obtained the values of ρ or γ from Auerbach and Kotlikoff (1987).

(2) If the study uses various values, the base value is indicated.

Source: By the author, using data from preceding studies.

Second, the estimation of wage profile function [Equation (3)] is explained. This estimation was carried out using the following process. 1) Using data from the "Basic

 $^{^{29}\,}$ However, money amount data were deflated by the GDP deflator (base year 2008) only in the estimation of wage profile function.

Survey on Wage Structure" (Ministry of Health, Labour and Welfare), the employee compensation (per hour) of general workers (identified as regular employees) and that of part-time workers (identified as non-regular employees) were calculated. Moreover, the data for respective age groups were derived by linear interpolation using the data of five-year age categories. 2) Using data from the "Labor Force Survey" (Ministry of Internal Affairs and Communications), the proportions of regular employees and non-regular employees within total employees were calculated (five-year age categories). 3) Using the data of 1) and 2), the weighted average of employee compensation (per hour) at each age (21 - 64) was calculated (for the period of 2008-12). 4) Using the data of 3) (converted to a logarithm), the wage profile function [Equation (3)] was estimated using the model of Mincer (1974). Further, an AR1 model that has a first-degree auto-correlation in the error term was estimated by the maximum likelihood method. The results are shown in Table A2.

Table A2. Estimation Results of Wage Profile Function

ϕ_0	ϕ_1	ϕ_2		
5.436	0.099	-0.001		
(68.580)	(24.469)	(-23.165)		
S.E. = 0.019 . Adj.R ² = 0.990 .				

Note: Figures in parentheses are t-ratios.

A1.1.2 Firm sector

First, the capital-share value (base year 2012) in production function [Equation (8)] was calculated using the following process. 1) Labor-share value in production function was calculated as the ratio of compensation of employees to national income (at factor cost) from the NA (Cabinet Office). 2) Capital-share value was calculated by deducting the ratio of 1) from 1.

Second, the value of depreciation rate of physical capital was calculated with data from the "Gross Capital Stock of Private Enterprises" (Cabinet Office), using the following process. 1) Total consumption amount of fixed capital (total value of non-financial and financial incorporated enterprises) was calculated. 2) Total gross fixed assets amount (total value of tangible fixed assets of secondary industries, tangible fixed assets of tertiary industries, and intangible fixed assets of industry as a whole) were calculated. 3) The ratio of value of 1) to value of 2) was calculated on an annually basis. 4) The average value of 3) for the period of 2000 - 12 was adopted as the value of depreciation rate of physical capital.

Third, the base fiscal year (fiscal year 2012) value of physical capital stock was calculated with data from the NA, using the following process. 1) The total net outstanding financial assets amount of the private sector (total value of the net outstanding financial assets of financial corporations, non-financial corporations, households, and private non-profit institutions serving households) were calculated. ³⁰ 2) The value of the physical capital stock was calculated by deducting the net outstanding financial liabilities amount of the general government³¹ from the value described in the above item 1).

Forth, the scale parameter is explained. This parameter value (base year 2012) was calibrated using the following data: the parameter values calculated so far, the value of physical capital stock, the value of total effective labor measured in efficiency units (calculated using the PPJ data and the wage profile function), and GNI (from the NA).

Fifth, the method of estimating the technological-progress-rate value is explained. Following Kamada and Masuda (2001) and Miyazawa (2008), I first set the production function as shown below in order to estimate the technological-progress-rate value. Furthermore, I set the Solow residual³² as total factor productivity (TFP).

$$Y_t = A\{(u_t^K K_t)^{\alpha} [(1+\lambda)^t u_t^L L_t]^{1-\alpha}\}$$
(A1)

$$TFP_t = \log A + (1 - \alpha) \log(1 + \lambda)t$$

= $\log Y_t - \alpha \log u_t^K - \alpha \log K_t - (1 - \alpha) \log u_t^L - (1 - \alpha) \log L_t$ (A2)

In these equations, Y_t represents GDP in period t, K_t the total physical capital stock, L_t the total supply of labor hours, u_t^K the capital utilization ratio, and u_t^L the labor force utilization ratio. In addition, A represents the scale parameter, α the capital income share, and λ the technological progress rate. Moreover, t represents a quarter of a year and log denotes natural logarithms.

Subsequently, I carried out the following preparations in order to estimate the technological-progress-rate value based on the above Equation (A2).

Firstly, the data of total physical capital stock, the total supply of labor hours, the capital utilization ratio, and the labor force utilization ratio were prepared. An over-

³⁰ When explained using Equation (28) of Section 3, the calculation here is as follows: $K_t = PA_t + (PFUND_t - TDEBT_t)$.

³¹ The general government consists of the central government, local governments, and social security funds.

³² See Solow (1957) for the Solow residual.

view of the calculation method related to these data and the data sources are shown in Tables A3 - A6.

No.	Item	Data	Processing	Source
1	Total physical capital stock	Tangible fixed assets of secondary and tertiary industries (excluding construction in progress)	Total value	"Gross Capital Stock of Private Enterprises" (Cabinet Office)
2	Capital	Secondary industries: Manufacturing industries' seasonally-adjusted index of capacity utilization ratio (linked index)	Relative value during period targeted for estimation (against maximum value = 100)	"Indices of Industrial Production" (Ministry of Economy, Trade and Industry)
	utilization ratio	Tertiary industries: Estimated value of capacity operating ratio of non- manufacturing industries		See Table A4.
3	Total supply of labor hours	Population aged 15+, maximum value of labor participation rate, maximum value of total labor hours (per person)	Total supply of labor hours = Product of three variables in "Data" column	See Table A6.
4	Labor force	Number of employed persons,	Labor supply hours = Product of two variables in "Data" column.	See Table A6.
4	utilization ratio	total labor hours (per person)	Labor force utilization ratio is the ratio of Labor supply hours to Total supply of labor hours.	Item 3

Table A3. Data of Equation (A2)

No.	Item	Data	Processing	Source
1	Electric power usage rate	Electric power consumption (other-total category)	Relative value during period targeted for estimation (against maximum value = 100)	"Electricity Demand of Large demand Industries" (Federation of Electric Power Companies)
2	Production capacity Large, Medium-sized, an BSI Small corporations categ		Relative value during period targeted for estimation (against maximum value = 100)	"Business Outlook Survey" -(Ministry of Finance)
	DOI	Sman corporations category	Weighted average using ratios by capital size in Item 3	(ministry of Finance)
3	Other tangible fixed assets	Data by capital size (all-industry category)	Ratio by capital size to total value	"Financial Statements Statistics of Corporations by Industry" (Quarterly Survey) (Ministry of Finance)
4	Estimated value of COR	 Estimated value of COR: Estimated value of COR Theoretical value of Electric power usage rate -Q3's impact Estimation of Electric power usage rate for 1) (by OLS) Electric power usage rate (Item 1) was regressed on BSI (Item 2) and Q3 dummy. 		See Table A5. Sample period: 1998 Q2 - 2013 Q4

Table A4. Capacity Operating Ratio (COR) of Non-manufacturing Industries

Table A5. Estimation Results of COR of Non-manufacturing Industries

Constant	BSI	Q3			
0.704	0.005	0.081			
(126.252)	(3.314)	(8.010)			
S.E. = 0.035 . Adj.R ² = 0.539 .					

Note: Figures in parentheses are t-ratios.

No.	Item	Data	Processing	Source
1	Population aged 15+	Population aged 15-64, population aged 65+	Total value	"Labor Force Survey" (Ministry of Internal Affairs and Communications)
2	Number of employed persons			(same as Item 1)
3	Labor participation rate	Number of employed persons (Data 3-1), number of unemployed persons (Data 3-2)	Ratio of Data 3-1 to sum of Data 3-1 and Data 3-2	(same as Item 1)
4	Maximum value of labor participation rate	1988 Q4 value (based on GDP gap and unemployment rate changes)		Item 3
5	Total labor hours (per person) (30 employees and greater)	Scheduled hours worked, non-scheduled hours worked	Relative value (against 2010 average = 100)	"Monthly Labour Survey" (Ministry of Health, Labour and Welfare)
			Total value	
6	Maximum value of total labor hours (per person) (30 employees and greater)	1988 Q4 value (based on GDP gap and unemployment rate changes)		Item 5

Table A6. Total Supply of Labor Hours

Next, the capital-income-share value was derived by the following process. 1) Value 1 was derived using data from the NA: Value 1 = GDP – Compensation of employees – Consumption of fixed capital – Taxes on production and imports + Subsidies (displayed in amount). 2) The ratio of compensation of employees to Value1, namely the labor-income-share value, was calculated. 3) Capital-income-share value was obtained by deducting the value of 2) from 1.

Finally, the values of TFP were calculated based on Equation (A2), using the parameters and data prepared thus far.

Following the preparations described above, I obtained the coefficient for deriving the value of technological progress rate by regressing TFP values on time trend (t), Q1 dummy, and Q3 dummy, in accordance with Equation (A2). Furthemore, in this estimation, an AR1 model that has a first-degree autocorrelation in the error term was estimated by the maximum likelihood method (sample period from 1997 Q1 to 2013 Q1). The results are shown in Table A7.

Constant	t	Q1	$\mathbf{Q3}$		
-3.86759	0.002	0.283	0.133		
(-172.384)	(3.988)	(29.364)	(13.779)		
S.E. = 0.045 . Adj.R ² = 0.893 .					

Table A7. Estimation Results of TFP

Note: Figures in parentheses are t-ratios.

The estimated value of the technological progress rate (λ) on a quarterly base was calculated using the estimated coefficient of the time trend in Table A7 and capital-income-share value. Finally, I converted this quarterly-based estimated value into the annually-based estimated value of the technological progress rate and utilized the latter value.

A1.1.3 Government sector

First, the value of labor income tax rate was calculated as follows, using data from the NA. 1) Value 1 was derived: Value 1 = National income (at factor cost) – Receipt of interests (displayed in amount). 2) The value of labor income tax rate was calculated as the ratio of tax revenue on labor income to Value 1 (base fiscal year 2012 value). Additionally, the value of pension income tax rate was set to be the same as that of the labor income tax rate.

Second, the value of interest tax rate was calculated as the ratio of other-current-tax revenue to receipt of interest, using data from the NA (base fiscal year 2012 value).

Third, the value of consumption-based tax rate was derived by the following process. 1) This value was derived at the time of the 5% consumption tax rate as follows using data from the NA:

- a. Value 1 was derived: Value 1 = Taxes on production and imports Subsidies (displayed in amount).
- b. Value 2 was derived: Value 2 = Private final consumption expenditure + Government final consumption expenditure (displayed in amount).
- c. The ratio of Value 1 to Value 2 was used as the value of consumption-based tax rate at the time of the 5% consumption tax rate (base fiscal year 2012 value).

2) Using the amount of consumption tax from "Ministry of Finance Statistics Monthly"

(Ministry of Finance) and the value of national income (at factor cost) from the NA, the ratio of the former to the latter was calculated. This is the value of consumption tax rate on national income at the time of the 5% consumption tax rate. Furthermore, using this consumption-tax-rate value, I also calculated the value (average value of fiscal years 2010 - 12) of consumption tax rate on national income corresponding to a consumption tax rate of 3%. 3) Using the values prepared in steps 1) and 2), the values of consumption-based tax rate were calculated in accordance with the government's schedule for raising the consumption tax rate.³³

Forth, the value of subsidy rate related to the fixed payment portion of public pensions is the value used under the system implemented from fiscal year 2009.

A1.1.4 Public pension sector

First, the values of public pension contribution rates (on labor income) are consistent with the default values of Japan's Employee's Pension Insurance and the raised value planned for the future. Second, the values of ratios used to calculate the remuneration-based portion of pension benefits are those used in Employee's Pension Insurance.³⁴ The ratio for the generation born in and before 1944 is assumed to be the same as that for the generation born in 1945.

A2. Data

This section discusses the data used in this study. Here, note that the money amount data are deflated by the GDP deflator (2005 = 100) from the NA.

A.2.1 Household sector

First, the initial values of assets held by transition generations, namely the assets as of the end of fiscal year 2011 were calculated using the following process. 1) The total net outstanding financial assets amount of the private sector, namely the total value of the net outstanding financial assets of financial corporations, households, and private non-profit institutions serving households, was calculated using data from the NA. 2)

³³ The consumption tax rate was raised to 8% from April 1, 2014. In addition, the Japanese government plans to raise the consumption tax rate to 10% from April 1, 2017.

³⁴ Furthermore, the values of ratios for the generations born from 1945-75 were calculated by incorporating the actual benefit amount status into the values of ratios of the generation born in 1976. The data of the actual benefit amount were obtained from the "Overview of the Employee's Pension Insurance and National Pension Service" (Ministry of Health, Labour and Welfare).

The ratio of net assets at each age to net assets at the age of 21 was calculated using data on the amount of savings and liabilities per household (for each age category). These data were from the "Annual Report on the Family Income and Expenditure Survey" (Ministry of Internal Affairs and Communications).³⁵ 3) Finally, the initial values of assets held by each generation were calculated from the data prepared in steps 1) and 2) and the population of each age group (from the PPJ).

Second, let us look at the data related to pension benefits. Firstly, the values of the fixed payment portion in pension benefits are consistent with the default values of the benefit amount of the National Pension (Basic Pension) and the raised values planned for the future. Secondly, the average annual labor income [*PVAI* in Equation (4)] for each transition generation is calculated from the following two factors: 1) labor income in and prior to fiscal year 2011, 2) labor income in and from fiscal year 2012. The latter value is determined endogenously within the simulation, whereas the former is calculated from the standard labor income (the actual basis for calculating the remuneration-based benefit amount) in fiscal year 2012, in accordance with the number of years worked until fiscal year 2011. This standard labor income is obtained from the "Overview of the Employee's Pension Insurance and National Pension Service" (Ministry of Health, Labour and Welfare).

A.2.2 Population (future population projections)

See Section 4.2.2.

A.2.3 Firm sector

The initial value (namely, the value as of the end of fiscal year 2011) of physical capital stock per unit of effective labor was obtained using the following process. 1) The total net outstanding financial assets amount of the private sector (the total value of net outstanding financial assets of financial corporations, households, and private non-profit institutions serving households) was calculated using data from the NA. 2) The value of physical capital stock was calculated by deducting the net outstanding financial liabilities amount of general government from the value of 1). 3) The quantity

³⁵ However, since the data in the "Annual Report on the Family Income and Expenditure Survey" are organized in five-year age groups, I created data for each year of age using the following method: 1) Data for ages 21-67 were estimated by linear interpolation. 2) Values for ages 68-85 were set to be the same as the value for age 67. 3) Data for ages 86-105 were estimated by linear interpolation so that net outstanding assets would be zero at the time of age 105.

of total effective labor was calculated from the population of each age group (from the PPJ) and the wage profile function [Equation (3)]. 4) Finally, the initial value of physical capital stock per unit of effective labor was obtained by dividing the value of 2) by the value of 3).

A.2.4 Government sector

The amount of GAE and that of EAE in the base fiscal year 2012 were calculated using the following process. 1) The total amount of government annual expenditure was calculated as the sum of the values of government final consumption expenditure and general government's gross capital formation from data of the NA (displayed in amount). 2) Furthermore, the amount of social transfers in kind from general government to households, obtained from the NA, was assumed to be the total amount of EAE. 3) The population aged 21 and over was calculated from the PPJ data. 4) The population aged 65 and over was also calculated. 5) The amount of government annual expenditure per member of the population aged 21 and over was calculated by dividing the value of 1) by that of 3). 6) The ratio of the total amount of EAE to that of government annual expenditure was then obtained from the product of the value of 5) and "1 – the value of 6)". 8) Meanwhile, the amount of EAE was calculated by dividing the value of 2) by the value of 4).

A.2.5 Total assets, public pension assets, and government sector outstanding debt

The initial values (namely, the values as of the end of fiscal year 2011) of the total assets of Japan as a whole, public pension assets, and the government sector's outstanding debt were calculated from the NA data as follows. 1) The total value of net outstanding financial assets of financial corporations, households, and private non-profit institutions serving households was set as the amount of total assets of Japan as a whole. 2) The net outstanding financial assets amount of the social security funds was set as the amount of public pension assets. 3) The total value of net outstanding financial liabilities amount of the central government and local governments was set as outstanding government debt amount.

 $^{^{36}}$ In this case, the fiscal year value is used for the value of 1), because the value of 2) is the fiscal year value.

References

- Abel, A. B., N. G. Mankiew, L. H. Summers, and R. J. Zeckhauser (1989) "Assessing Dynamic Efficiency: Theory and Evidence," *Review of Economic Studies*, Vol. 56, No.1, pp. 1-19.
- Auerbach, A. J. and L. J. Kotlikoff (1983) "National Savings, Economic Welfare, and the Structure of Taxation," in Feldstein, M. eds., *Behavioral Simulation Methods in Tax Policy Analysis,* Chicago: The University of Chicago Press.
- Auerbach, A. J. and L. J. Kotlikoff (1987) *Dynamic Fiscal Policy*, Cambridge: Cambridge University Press.
- Auerbach, A. J., L. J. Kotlikoff, R. P. Hagemann, and G. Nicoletti (1989) "The Economic Dynamics of an Aging Population: The Case of Four OECD Countries," *OECD Working Papers*, No.62.
- Baltensperger, E. and T. J. Jordan (1997) "Principles of Seigniorage," Swiss Journal of Economics and Statistics, Vol. 133, pp. 133-152.
- Baltensperger, E. and T. J. Jordan (1998) "Seigniorage and the Transfer of Central Bank Profits to the Government," *KYKLOS*, Vol. 51, no. 1, pp. 73-88.
- Bohn, H. (1998) "The Behavior of U.S. Public Debt and Deficits," *The Quarterly Journal of Economics*, Vol. 113, No. 3, pp. 949-963.
- Börsch-Supan, A., A. Ludwig, and J. Winter (2001) "Aging and International Capital Flows," NBER Working Paper 48553.
- Börsch-Supan, A., A. Ludwig, and J. Winter (2005) "Aging, Pension Reform, and Capital Flows: A Multi-country Simulation Model," NBER Working Paper 11850.
- Broda, C. and D. E. Weinstein (2005) "Happy News from the Dismal Science: Reassessing the Japanese Fiscal Policy and Sustainability," in Ito, T., H. Patrick, and D. E. Weinstein eds., *Reviving Japan's Economy*, Cambridge: The MIT Press.
- Detken, C. (1999) "Fiscal Policy Effectiveness and Neutrality Results in a Non-Ricardian World," *European Central Bank Working Paper Series,* No.3.
- Doi, T., T. Hoshi, and T. Okimoto (2011) "Japanese Government Debt and Sustainability of Fiscal Policy," *Journal of the Japanese and International Economies*, Vol. 25, pp. 414-433.
- Domar, E. D. (1944) "The 'Burden of Debt' and the National Income," *American Economic Review* Vol. 34, No.4, pp. 798-827.
- European Commission (2006) "The Long-term Sustainability of Public Finances in the European Union," European Economy, No.4
- Fougère, M. and M. Mérette (1999) "Population Aging and Economic Growth in Seven

OECD Countries," Economic Modelling, Vol. 16, pp.411-427.

- Fukuda, S. and H. Teruyama (1994) "The Sustainability of Budget Deficits in Japan," *Hi-totsubashi Journal of Economics*, Vol. 35, No. 2, pp. 109-119.
- Hamilton, J. D. and M. A. Flavin (1986) "On the Limitations of Government Borrowing: A Framework for Empirical Testing," *American Economic Review*, Vol. 76, No.4, pp. 808-819.
- Hoshi, T. and T. Ito (2014) "Defying Gravity: Can Japanese Sovereign Debt Continue to Increase without a Crisis?" *Economic Policy January 2014*, pp. 5-44.
- Hviding, K. and M. Mérette (1998) "Macroeconomic Effects of Pension Reform in the Context of Aging Populations: Overlapping Generations Model Simulations for Seven OECD Countries," *OECD Working Papers*, No.201.
- Ihori, T., T. Doi, and H. Kondo (2001) "Japanese Fiscal Reform: Fiscal Reconstruction and Fiscal Policy," Japan and the World Economy, Vol. 13, pp. 351-370.
- Ihori, T., R. R. Kato, M. Kawade, and S. Bessho (2006) "Public Debt and Economic Growth in an Aging Japan," in Kaizuka, K. and A. O. Kruger eds., *Tackling Japan's Fiscal Challenges*, New York: Palgrave Macmillan.
- Ito, A., T. Watanabe, and T. Yabu (2011) "Fiscal Policy Switching in Japan, the US, and the UK," *Journal of the Japanese and International Economies*, Vol. 25, pp. 380-413.
- Iwamoto, Y., R. Kato, and M. Hidaka (1993) "Public Pensions and an Aging Population," *Review of Social Policy*, Vol. 2, pp. 1-10.
- Kamada, K. and K. Masuda (2001) "Effects of Measurement Error on the Output Gap in Japan," Monetary and Economic Studies (the Bank of Japan's Institute for Monetary and Economic Studies), Vol. 19, No.2, pp.109-154.
- Kato, R. (1998) "Transition to an Aging Japan: Public Pension, Savings, and Capital Taxation," *Journal of the Japanese and International Economies*, Vol. 12, pp. 204-231.
- Kato, R. R. (2002) "Government Deficit, Public Investment, and Public Capital in the Transition to an Aging Japan," *Journal of the Japanese and International Economies*, Vol. 16, pp. 462-491.
- Krichel, T., P. Levine, and J. Pearlman (1996) "Fiscal and Monetary Policy in a Monetary Union: Credible Inflation Targets or Monetized Debt?" Weltwirtschaftliches Archiv 1996, Vol. 132, No. 1, pp. 28-54.
- Miles, D. (1999) "Modeling the Impact of Demographic Change upon the Economy," *Economic Journal*, Vol. 109, No. 452, pp. 1-36.
- Mincer, J. A. (1974) "The Human Capital Earnings Function," in Mincer, J. A. eds., Schooling, Experiences, and Earnings, New York: Columbia University Press.
- Miyazawa, K. (2008) "The Decline in Capital Utilization and TFP in the 1990s," RIETI

Discussion Paper Series, Research Institute of Economy, Trade & Industry, 08-J-054. (In Japanese)

- Neumann, M. J. M. (1992) "Seigniorage in the United States: How Much Does the U.S. Government Make from Money Production?" *Federal Reserve Bank of St. Louis Review*, Vol. 74, No. 2, pp. 29-40.
- Oguri, S. (2006) "Central Banking and Seigniorage," *The Annals of Human and Social Sci*ences (Faculty of Economics Shiga University), Vol. 13, pp. 19-35. (In Japanese)
- Reserve Bank of Australia (1997) "Measuring Profits from Currency Issue," *Reserve Bank of Australia Bulletin*, July 1997, pp.1-4.
- Sadahiro, A. and M. Shimazawa (2002) "The Computable Overlapping Generations Model with an Endogenous Growth Mechanism," *Economic Modelling*, Vol. 20, pp. 1-24.
- Sakuragawa, M. and K. Hosono (2011) "Fiscal Sustainability in Japan," *Journal of the Japanese and International Economies*, Vol. 25, pp. 434-446.
- Sargent, T. J. (1999) "A Primer on Monetary and Fiscal Policy," Journal of Banking & Finance, Vol. 23, pp. 1463-1482.
- Sargent, T. J. and N. Wallance (1981) "Some Unpleasant Monetarist Arithmetic," Federal Reserve Bank of Minneapolis Quarterly Review, Vol. 5, No. 3, pp. 1-17.
- Schobert, F. (2000) "Seigniorage: An Argument for a National Currency?" Center for European Studies Working Document, No. 174.
- Seater, J. U. (1993) "Recardian Equivalence," *Journal of Economic Literature*, Vol. 31, No. 1, pp. 142-190.
- Shimazawa, M. and K. Oguro (2010) "Impact of Immigration on the Japanese Economy: A Multi-country Simulation Model," *Journal of the Japanese and International Economies*, Vol. 24, pp. 586-602.
- Solow, R. M. (1957) "Technical Change and the Aggregate Production Function," *The Review and Economics and Statistics*, Vol. 39, No. 3, pp.312-320.
- Tanner, E. and J. Devereux (1993) "Deficits and the Demand for Money," Southern Economic Journal, Vol. 60, No. 2, pp. 316-326.
- Ueda, J. and T. Sugiura (2011) "Simulation Analysis of Japan's Fiscal Sustainability," Public Policy Review (Ministry of Finance, Japan), Vol. 7, No. 2, pp. 299-336.