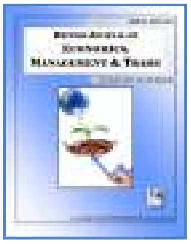

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Budget Deficits and Long-Term Interest Rates in Japan

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Authors' contributions

This work was carried out in collaboration between the two authors. Both authors wrote the paper, read it, and approved the final manuscript.

Research Article

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ABSTRACT

The effect of budget deficits on the economy is one of the most important unresolved issues in public economics and macroeconomics. Based on a simple loanable funds model that describes the relationship between budget deficits and long-term interest rates, this study empirically quantifies how Japan's large budget deficits affects long-term interest rates and the slope of the yield curve in Japan. Estimation based on the quarterly data for the period 1981.II-2009.I reveals statistically significant evidence of the positive link between budget deficits and long-term interest rates. This finding supports the Keynesian view of the budget deficit and is generally consistent with the recent studies that employed improved and expanded dataset in the United States.

Keywords: Budget deficits; long-term interest rates; yield curve; cointegration; Fisher hypothesis.

1. INTRODUCTION

The effect of budget deficits on the economy is one of the most important unresolved issues in public economics and macroeconomics [1]. Although many economists believe that large budget deficits are harmful for the economy, there is considerable debate over their exact

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impact on prominent macroeconomic variables. The effect on long-term interest rates is of particular interest due to its potential effect on long run economic growth. Researchers including Ball and Mankiw [2] maintain that budget deficits reduce national savings and thereby the supply of loanable funds, which exerts an upward pressure on long-term interest rates. As a result, large budget deficits may potentially crowd out private investment, which subsequently suppresses economic growth in the long run.

The study on the link between budget deficits and long-term interest rates was sparked by the emergence of large budget deficits in the United States in the 1980s. Early empirical investigations include Plosser [3], Hoelscher [4], Makin [5], Mascaro and Meltzer [6], Evans [7], and Evans [8]. These studies generally found inconclusive evidence on the relationship between budget deficits and long-term interest rates in the United States. Subsequent studies employed improved and expanded dataset. These studies tend to find a positive and statistically significant relationship between budget deficits and long-term interest rates in the United States; See Hoelscher [9], Feldstein [10], Cebula and Hung [11], Cebula and Rhodd [12], Reinhart and Sack [13], Cebula [14], Cebula [15], Laubach [16], Cebula and Cuellar [17]. Kiani [18] reported that the relationship becomes statistically significant only in the period after 1980, in which the financial market has become more reactive to expansions in fiscal expenditures with the emergence of large budget deficits.

Historically, fiscal position has been relatively in good standing in Japan. Outstanding long-term debt has been maintained below 60% of GDP during the 1970s and 1980s. However, the collapse of the bubble economy in the early 90s hampered this trend. As shown in Fig. 1, fiscal balance has persistently deteriorated over the last two decades, due to expansionary fiscal policies coupled with a decline in tax revenues which are sensitive to business cycle fluctuations. Outstanding long-term debt has also expanded drastically from 59% of GDP in 1991 to 136% of GDP in 2001 that escalated further to unprecedented over 170% of GDP in 2009.

Despite seemingly critical fiscal situations of Japan, the literature on the relationship between budget deficits and interest rates focused on Japan is sparse. Among a few studies, Nakazato et al. [19] employed a simple OLS method and found insignificant effects of budget deficits and outstanding debt on nominal interest rates in Japan. Kameda [20] used budget projections officially published by the government and found a statistically significant relationship between projected budget deficits and long-term interest rates. However, these studies do not adequately address time series properties of the dataset, and the validity of their econometric analyses are questionable.

The reason for the paucity of research on this subject in Japan may stem from the fact that a usable form of data had not been easily available for empirical analysis. For example, when the System of National Accounts (SNA) was changed from SNA68 to SNA93, the Japanese government re-calculated budget deficits data based on SNA93 only back to 1980. Because of this, it had been difficult to obtain a reasonable number of observations on budget deficits for time series analysis. Another example is expected inflation. Historical data on expected inflation based on survey methods like Michigan Median Survey of inflation expectations (for USA) is not available in Japan.

In this study, we attempt to add new empirical evidence on the relationship between budget deficits and long-term interest rates by focusing on time series data outside the United States. Many of the previous studies are based on US data, but the findings may not hold for other economies which have different economic structures. We aim to expand previous research by focusing on Japan, which has also very large budget deficits and outstanding debt. In particular, this study empirically quantifies how Japan's large budget deficits affected long-term interest rates and the slope of the yield curve.

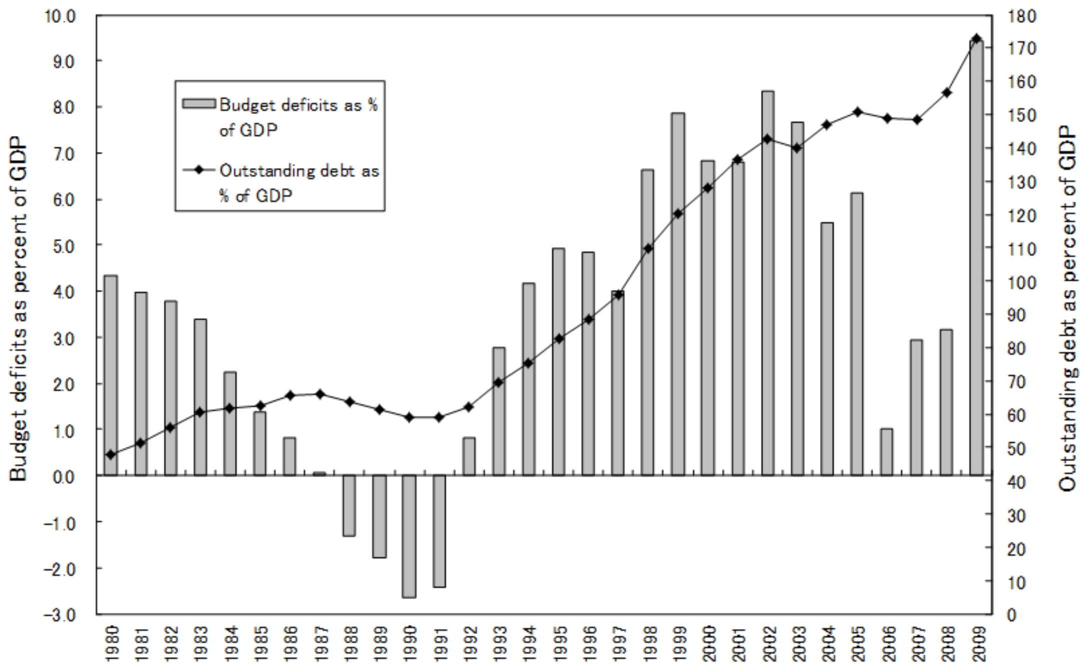

Fig. 1. Budget deficits and outstanding debt as percent of GDP
Note: Negative values of budget deficits represent budget surplus.
Source: Authors' calculations based on the Annual Report on National Accounts, the Cabinet Office, and the Annual Report on Government Bonds, the Ministry of Finance

The paper is organized as follows. Section 2 presents the theoretical model. Section 3 explains construction of variables. Section 4 analyzes time series properties of the variables. Section 5 presents the results of the econometric analyses, and section 6 provides conclusions.

2. THEORETICAL MODEL

We employ a loanable funds model presented in Kiani [18], which is constructed based on Sargent [21], Echols and Elliot [22], Hoelscher [9], Cebula and Hung [11], Cebula and Rhodd [12]. Loanable funds model is also employed in some of the recent studies on this topic [14,15,17].

Kiani [18] considers a simple model of long-run interest rates, wherein the interest rates equilibrate the flow supply (S_{LF}) and flow demand (D_{LF}) for loanable funds given in equations (1) and (2):

$$S_{LF} = a_1 + b_1 i^L + c_1 r^s + d_1 \pi^e + e_1 CYCLE + f_1 DEF \tag{1}$$

$$D_{LF} = a_2 + b_2 i^L + c_2 r^s + d_2 \pi^e + e_2 CYCLE + f_2 DEF \quad (2)$$

The variable i^L represents long-term interest rates, r^s represents ex ante real short-term interest rates, π^e represents expected inflation, CYCLE represents business cycle conditions, and the variable DEF represents budget deficits.

In equation (1), the quantity of long-term supply for loanable funds should respond positively to long-term interest rates ceteris paribus, and therefore we expect $b_1 > 0$. Higher values of expected real short-term interest rates make short term loans relatively favorable among a different choice of maturities and discourage lenders to lend long. Therefore, we expect its coefficient to be negative $(c_1 < 0)$. Higher inflation also reduces the willingness to lend long because investors can invest in alternative debt instruments such as equities and real estate, whose returns are less affected by high inflation. Therefore, we expect its coefficient to be negative $(d_1 < 0)$. An increase in economic activity increases the supply for long-term funds and therefore its coefficient is expected to be positive $(e_1 > 0)$. If the agents are sufficiently forward-looking, an increase in government debt causes rational agents to increase their savings in anticipation of future taxes, thereby increasing the supply of funds when budget deficits increase $(f_1 > 0)$. In the case of myopic agents, the supply of funds is independent of budget deficits, and thus $f_1 = 0$.

In equation (2), higher long-term interest rates reduce the demand for long-term borrowing, and therefore we expect a negative sign on its coefficient $(b_2 < 0)$. An increase in short-term real interest rates causes borrowers to increase long-term borrowing $(c_2 > 0)$ because long-term borrowing becomes relatively cheaper ceteris paribus. An increase in expected inflation reduces the cost of borrowing and therefore we expect $d_2 > 0$. Strong macroeconomic conditions raise the willingness to incur debt by firms and consumers, and therefore we expect $e_2 > 0$. Finally, the demand for funds increases with large budget deficits ceteris paribus due to expansions in fiscal expenditures $(f_2 > 0)$.

Solving equations (1) and (2) for the equilibrium long-term interest rate yields the following equation:

$$i^L = \frac{(a_2 - a_1) + (c_2 - c_1) r^s + (d_2 - d_1)\pi^e + (e_2 - e_1) CYCLE + (f_2 - f_1) DEF}{(b_1 - b_2)} \quad (3)$$

Based on this, we employ the following equation for the empirical evaluation of the impact of budget deficits on long-term interest rates:

$$i_t^L = \beta_0 + \beta_1 r_t^s + \beta_2 \pi_t^e + \beta_3 DEF_t + \beta_4 CYCLE_t + u_t \quad (4)$$

where u_t is an error term. Comparing equations (3) and (4) by taking into account the above discussions, the signs of the coefficients in equation (4) are predicted to be as follows.

The coefficients of ex-ante real short-term interest rates (r^s) and expected inflation (π^e) are expected to be positive. The effect of business cycle conditions (CYCLE) is ambiguous.

The principal purpose of this study is to investigate the sign, magnitude, and statistical significance of the coefficient on the deficit variable (β_3). The theoretical prediction of the sign on DEF depends on the specific views considered. The traditional view or Keynesian view of government deficits postulates agents are myopic (in an extreme case, $f_1 = 0$) and therefore the sign on DEF is positive [14]. The Ricardian view suggests that an increase in the demand for funds due to large budget deficits is offset by an increase in private saving and the sign on DEF is nonpositive [23].[1] Thus, the main hypothesis of this study can be expressed as follows:

H_0: $\beta_3 > 0$ (The traditional or Keynesian view)

H_1: $\beta_3 \leq 0$ (The Ricardian view).

While our primary focus is the effect of the deficit variable (β_3), the formulation also allows us to test whether the Fisher hypothesis holds for Japan. A strong form of the Fisher hypothesis predicts that there is one for one movement between nominal interest rates and expected inflation, which implies $\beta_2 = 1$. Thus, we have the following hypothesis:

H_0: $\beta_2 = 1$ (if the Fisher hypothesis holds)

H_1: $\beta_2 \neq 1$ (if the Fisher hypothesis does not hold).

3. CONSTRUCTION OF VARIABLES

This section describes how the variables used in the empirical analyses are constructed. Please refer to the Appendix for more details.

3.1 Measures of Expected Inflation and Interest Rates

As is shown in the previous section, we need a measure of expected inflation for implementation of our empirical exercise. Expected inflation based on survey methods like Michigan Median Survey of inflation expectations (for USA) is not available in Japan.[2] Therefore, we use a measure of expected inflation based on adaptive expectations. Adaptive expectations forecast future inflation by a weighted average of past inflation. We employ a specification due to Gordon [25] and Kamada [26].

$$\pi_t^e = \theta \sum_{i=1}^{4} \pi_{t-i} / 4 + (1-\theta) \sum_{i=5}^{8} \pi_{t-i} / 4$$

where θ is estimated by regressing actual inflation on the weighted average of the past inflations.

[1] Studies by Evans [7] and Evans [8] reported counterintuitive findings that larger deficits reduce interest rates.
[2] This type of survey has started only since 2001 in Japan. There are several published articles that apply the method proposed by Carlson and Parkin [24] to Japan, but this method is known to be dependent on very restrictive distributional assumptions.

Concerning interest rates, short-term interest rate is measured by the money market rate, and long-term interest rate is measured by the government bond yield with 10-year maturity. Ex ante real short-term interest rates are constructed as the difference between money market rate and expected inflation, where expected inflation is derived by the method explained above.

3.2 Measures of budget deficits

We use two measures of budget deficits. The first measure of budget deficits (DEF_1) is the ratio of budget deficits to nominal GDP:

$$\text{DEF\_1} = \frac{\text{Budget deficit}}{\text{Nominal GDP}} \times 100 .$$

However, it is well known that nominal budget deficits have a tendency to overstate real deficits due to inflation [1]. Intuitively, like any debt, inflation works favorably toward borrowers. Thus real government debt becomes smaller than nominal debt in the presence of inflation. We employ the following real measure of budget deficits (DEF_2) to resolve this issue:

$$\text{DEF\_2} = \frac{\text{Budget deficit} - \pi \text{D}}{\text{Nominal GDP}} \times 100 ,$$

where π is inflation rate and D is nominal outstanding debt. Nominal budget deficits overstate real budget deficits by πD, which is the change in outstanding debt due to inflation. Thus we subtract πD from nominal deficits to construct a real measure of budget deficits.

Our measure of budget deficits is based on the difference between savings and investment of the general government, which is a consolidation of national and local governments plus social security fund. The figures are based on the System of National Accounts 1993 (SNA93). When the System of National Accounts was changed from SNA68 to SNA93, the Japanese government re-calculated historical data based on SNA93 only back to 1980. Since the two budget deficits data (SNA68 and SNA93) do not exactly match each other, we base our budget deficit data on SNA93. This gives us annual data from 1981 to 2009. If we calculate the ratio of budget deficits to nominal GDP using the quarterly data on GDP, the ratio will have undesirable jumps at the end of each fiscal year. In order to avoid this problem, smoothed budget deficit data are used in calculating this ratio. In particular, we use the quadratic interpolation method outlined in Goldstein and Khan [27] to convert the annual series into smoothed quarterly series. This method has been used in many other studies such as Goldstein and Khan [28], Arize [29], and Weliwita and Ekanayake [30]. By this operation, we are implicitly assuming that budget deficits change smoothly over time rather than fluctuate quarter by quarter. Franses et al. [31] demonstrated that when generated series are used, OLS standard errors would be biased and produce OLS t-ratios that will be biased upwards. This problem can be fixed by using the Newey-West HAC standard errors. We also interpolate yearly data on outstanding debt to produce smoothed quarterly data.
After these manipulations, we have usable quarterly data of all variables from the second quarter of 1981 to the first quarter of 2009.

4. TIME SERIES PROPERTIES AND ESTIMATION

4.1 Unit Root Tests

In examining time series data, a crucial first step is to investigate time series properties of individual variables. Depending on whether the variables are integrated or not, different econometric techniques need to be applied. We adopt the following three testing procedures for unit root: the Augmented Dickey-Fuller Test (ADF) due to Dickey and Fuller [32], the Phillips-Perron Test (PP) due to Phillips and Perron [33], and the Kwaiatkowski, Phillips, Schmidt, and Shin Test (KPSS) due to Kwaiatkowski et al. [34]. ADF is arguably the most widely used unit root test. PP is based on non-parametric methods and is consistent even in the presence of heteroskedastic errors. These two tests have the null hypothesis that the variable has a unit root. It is known, however, that the tests may suffer low power of correctly rejecting the null of unit root. To accommodate this issue, we also adopt KPSS, which has a null hypothesis that the variable is stationary.

Table 1. Unit root tests (1981.II-2009.I)

Variable name	Level			First difference		
	ADF	PP	KPSS	ADF	PP	KPSS
i_t^L (long-term interest rate)	-1.851	-1.849	1.065***	-9.959***	-9.985***	0.140
r_t^s (ex-ante real short-term interest rate)	-1.386	-1.439	0.896***	-7.013***	-6.657***	0.309
π_t^e (expected inflation)	-2.573	-4.395***	0.826***	-3.264**	-4.092***	0.340
DEF_1 (budget deficit)	-1.716	-1.167	0.494**	-2.722*	-5.197***	0.279
DEF_2 (budget deficits)	-1.863	-1.474	0.539**	-2.614*	-4.271***	0.092
CYCLE (business cycle conditions)	-5.959***	-6.051***	0.047	-8.309***	-10.432***	0.243

Notes: ADF refers to the Augmented Dickey-Fuller Test, PP refers to the Phillips-Perron Test, and KPSS refers to the Kwaiatkowski, Phillips, Schmidt, and Shin Test. For ADF and PP, the null hypothesis is the variable has a unit root, and for KPSS, the null is the variable is stationary. The tests are conducted including an intercept term
***** Statistically significant at the 1% level*
*** Statistically significant at the 5% level*
** Statistically significant at the 10% level*

The results of the unit root tests are shown in Table 1. Except business cycle conditions (CYCLE) and expected inflation (π_t^e), the results have clear indications that all variables are integrated of order 1, or I(1). The results for expected inflation (π_t^e) are mixed. While ADF and KPSS imply that it has a unit root, PP rejects the null of unit root. In view of this, we conducted additional unit root tests including Dickey-Fuller with GLS Detrending (Elliot *et al*.

[35]), Elliot, Rothenberg, and Stock Point Optimal [35], and Ng and Perron [36]. All these additional tests signaled that expected inflation is an I(1) variable at the 1 % significance level. Therefore, we treat expected inflation as an I(1) variable in the ensuing analyses. For business cycle conditions, all three tests indicate it is stationary in level. This implies that business cycle conditions, at least measured in this way, does not form long-run equilibrium relationships with other I(1) variables and therefore dropped from the ensuing analyses.

4.2 Cointegration Tests

Our interest is to estimate the equilibrium relationship involving long-term interest rates and budget deficits. Since the estimation equation comprises of nonstationary variables, we must be careful not to fall into spurious regression (Granger and Newbold, [37], Phillips [38]). If a true equilibrium relationship exists among nonstationary variables, their stochastic trends must be linked and they must be cointegrated.

We apply the Johansen methodology ([39], [40]) to test the existence of cointegration among long-term interest rates, real short-term interest rates, expected inflation, and budget deficits (either DEF_1 or DEF_2 variable is used). The Johansen methodology circumvents the use of two-step procedures which tend to amplify estimation errors, and can detect the possible existence of multiple cointegrating vectors. A lag length of six lags is chosen based on the likelihood ratio test.

We estimated the characteristic roots and calculated λ_{trace} and $\lambda_{\max}$ test statistics, where λ_{trace} is the trace statistic and $\lambda_{\max}$ is the maximum eigenvalue statistic. The results are shown in Table 2. For the variable DEF_1, both λ_{trace} and $\lambda_{\max}$ statistics indicate the existence of at least one cointegrating vector, rejecting the null of no cointegration at the 1% significance level. The results tend to show that there is exactly one cointegrating vector; At 5%, λ_{trace} test accepts the null of at most one cointegrating vector, and $\lambda_{\max}$ test supports the null of exactly one cointegrating vector over the alternative of two cointegrating vectors. However, we also note that this result does not hold if the 10% significance level is employed. For the variable DEF_2, regardless of whether we employ 5% or 10% significance level, both λ_{trace} and $\lambda_{\max}$ statistics clearly indicate that there is exactly one cointegrating vector. All in all, if we combine both theoretical and empirical evidences, we believe there is reasonable evidence that the equilibrium relationship involving long-term interest rates and budget deficits is characterized by exactly one cointegrating vector. Thus, we treat so in the following regression analyses.

Table 2. Cointegration test (1981.II-2009.I)

Null hypothesis	Alternative hypothesis	DEF_1		DEF_2	
		Test statistics	p-value	Test statistics	p-value
λ_{trace} tests		λ_{trace} value		λ_{trace} value	
r = 0	r > 0	69.499	0.0012	67.265	0.0022
r ≤ 1	r > 1	34.901	0.0537	30.855	0.1363
r ≤ 2	r > 2	14.127	0.2808	13.622	0.3162
$\lambda_{\max}$ tests		$\lambda_{\max}$ value		$\lambda_{\max}$ value	
r = 0	r = 1	34.598	0.0075	36.410	0.0041
r = 1	r = 2	20.774	0.0805	17.233	0.2195
r = 2	r = 3	11.296	0.2307	11.232	0.2351

Notes: r is the number of cointegrating vectors. λ_{trace} is the trace statistic and $\lambda_{\max}$ is the maximum eigenvalue statistic. The results in the column of DEF_1 are obtained using DEF_1 as a measure of budget deficits

4.3 Estimation of the Cointegrating Relationship

In estimating the cointegrating relationship involving long-term interest rates and budget deficits, several econometric methods are applied to check the robustness of the estimates. The maximum likelihood estimation of vector error correction model (VECM) proposed by Johansen [39,40] produces asymptotically efficient estimates of the cointegrating vectors as well as those of the short-run dynamics. Although Johansen's maximum likelihood is valid in large sample, it is reported that single-equation procedures may perform better in small sample [41]. Since our main interest is the long-run relationship captured in the cointegrating vector and the evidence suggests that there is exactly one cointegrating vector, the use of single-equation procedures may be preferred in this study. Therefore, we also apply fully modified OLS (FMOLS) proposed by Phillips and Hansen [42] and dynamic OLS proposed by Saikkonen [43] and Stock and Watson [41]. Fully modified OLS is an optimal single-equation technique which is asymptotically efficient. It corrects for both endogeneity and serial correlation effects, and enables valid inferences on parameter estimates by providing corrected t statistics which follow normal distribution asymptotically. Dynamic OLS augments the cointegrating regression with leads and lags of the first difference of the I(1) variables so that it corrects for potential simultaneity bias. The standard inferences based on t statistics are also valid asymptotically, where HAC (heteroskedasticity and autocorrelation consistent) standard errors are used to form t statistics.

5. REGRESSION RESULTS

The regression results based on Johansen maximum likelihood (Johansen ML), fully modified OLS (FMOLS), and dynamic OLS are presented in Table 3. The dependent variable is the long-term interest rate as measured by the government bond yield with 10-year maturity, and the independent variables are real short-term interest rates, expected inflation, and budget deficits (either DEF_1 or DEF_2 variable is used). The estimation period is from the second quarter of 1981 to the first quarter of 2009.

Generally speaking, the estimated values based on FMOLS and dynamic OLS are very close, while there are differences in estimated values between Johansen ML and the single-equation methods (FMOLS and dynamic OLS). The choice of budget deficits variables (DEF_1 or DEF_2) has only limited effect on estimates in general.

The coefficients for budget deficits are positive and consistently significant under single-equation models. Under Johansen ML, the coefficients are positive, but the magnitudes are smaller and statistically insignificant. The fact that the coefficients are insignificant under Johansen ML may stem from poorer small sample performance of Johansen ML compared to single-equation methods [41]. For example, like the budget deficits estimates, the estimated values for real interest rates (β_1) are smaller (may be downward biased) under Johansen ML compared to those under single equation models. Nonetheless, real interest rates are statistically significant under both Johansen ML and single equation models because the estimated values are sufficiently larger than 0. However, budget deficits estimates are much closer to 0 and therefore, the downward bias under Johansen ML may have caused the budget deficits coefficients to be insignificantly different from 0.

Table 3. Effect of budget deficits on long-term interest rates (1981.II-2009.I)

	JohansenML	**Johansen ML**	**FMOLS**	**FMOLS**	**Dynamic OLS**	**Dynamic OLS**
Constant	1.0568 (0.1892)***	1.2402 (0.1772)***	0.9138 (0.1957)***	0.9797 (0.1747)***	0.9590 (0.2316)***	1.0267 (0.2083)***
r_t^s (β_1)	0.6850 (0.0515)***	0.6386 (0.0479)***	0.8330 (0.0512)***	0.8177 (0.0496)***	0.8353 (0.0666)***	0.8143 (0.0675)***
π_t^e (β_2)	1.1343 (0.0703)***	1.1525 (0.0837)***	0.9610 (0.0550)***	1.0040 (0.0588)***	0.9468 (0.0515)***	0.9823 (0.0678)***
DEF_1 (β_3)	0.0593 (0.0316)		0.0899 (0.0311)***		0.0823 (0.0379)**	
DEF_2 (β_3)		0.0289 (0.0285)		0.0786 (0.0266)***		0.0709 (0.0343)**

Notes: The dependent variable is the long-term interest rate as measured by the government bond yield with 10-year maturity. Standard errors are shown in parentheses. Johansen ML refers to the Johansen maximum likelihood and FMOLS refers to the fully modified OLS.
For Johansen ML, only the coefficient estimates of the cointegrating vector are shown, and the significance of the coefficients are derived by likelihood ratio test.
**** Statistically significant at the 1% level*
*** Statistically significant at the 5% level*
** Statistically significant at the 10% level*

The definitions of the independent variables are as follows:

$$r_t^s \text{ = money market rate; } \pi_t^e = \theta\sum_{i=1}^{4}\pi_{t-i}/4 + (1-\theta)\sum_{i=5}^{8}\pi_{t-i}/4;$$

$$\text{DEF\_1} = \left[\frac{\text{Budget deficit}}{\text{Nominal GDP}}\right]\times 100; \qquad \text{DEF\_2} = \left[\frac{\text{Budget deficit - }\pi\text{D}}{\text{Nominal GDP}}\right]\times 100.$$

The estimates of budget deficits under FMOLS and dynamic OLS indicate that large budget deficits increased the demand for funds (f_2) more than the supply (f_1), causing the coefficient of the budget deficits (β_3) to be positive. Therefore, an increase in budget deficits causes the yield curve to slope upwards. These results support the Keynesian view of budget deficits and are generally consistent with the recent studies that employed improved and expanded dataset in the United States such as Reinhart and Sack [13] and Kiani [18].

Concerning comparisons with the previous studies that focused on Japan, our results do not support Nakazato et al. [19], which applied a simple OLS and found insignificant effects of budget deficits on nominal interest rates. Our estimates suggest that a 1 % increase in budget deficits relative to GDP will increase long-term interest rates within the range of approximately 0.07% - 0.09%. The estimated magnitudes are much smaller than those suggested by Kameda [20], which reported approximately 0.35%. We believe the estimates by Kameda are upward biased. For example, budget balance had persistently deteriorated in Japan during the 1990s, from a budget surplus of 1.8% in 1991 to a deficit of 6.1% of GDP in 2001. According to our results, the change in budget balance with this magnitude has translated into a 0.55% - 0.71% increase in long-term interest rates. The results by Kameda imply a 2.77% increase, but this seems at odds with the fact that the long-term interest rates have been maintained at fairly low levels (less than 1.5% most of the periods after 2000).

The coefficient estimates for real interest rates (β_1) are positive and statistically significant under all models. The magnitudes are fairly large (approximately 0.8). After the collapse of the bubble economy in the early 90s, the Bank of Japan gradually reduced its interest rate to zero. The estimates reflect the degree to which the interest cut successfully spilled over to pull down long-term interest rates.

Although the effect of budget deficits on long-term interest rates is our primary interest, this study also investigates if the Fisher hypothesis holds in Japan. According to the strong form of the Fisher hypothesis, there is a one-on-one relationship between expected inflation and nominal interest rates. The estimated values are close to 1, especially under FMOLS and dynamic OLS. For all models, the null hypothesis that $\beta_2 = 1$ cannot be rejected at the 5% significance levels (the null of $\beta_2 = 1$ is accepted). This result implies that the Fisher hypothesis is likely to hold in Japan.

6. CONCLUSIONS

In this study, we have empirically quantified how Japan's large budget deficits affected long-term interest rates and the slope of the yield curve based on the quarterly data for the period 1981.II-2009.I. The regression results under single-equation models show statistically significant evidence of the positive link between budget deficits and long-term interest rates, and support the Keynesian view of budget deficits. Although previous studies by Plosser [3], Hoelscher [4], Makin [5], Mascaro and Meltzer [6], Evans [7], and Evans [8] did not find any positive link between budget deficits and long-term interest rates, our regression results reveal that large budget deficits do increase the slope of the yield curve. This finding is consistent with the recent studies such as Reinhart and Sack [13], Cebula [14], and Kiani [18] that employed improved and expanded dataset of the United States. Our results also reveal that a strong form of the Fisher hypothesis holds for Japan.

The regression results indicate that a 1 % increase in budget deficits relative to GDP will increase long-term interest rates within the range of approximately 0.07% - 0.09%. If we have a 7.9% increase in budget deficits as was the case between 1991 and 2001, this can translate into a 0.55% - 0.71% increase in long-term interest rates ceteris paribus. Laubach [16] estimated that a one percentage point increase in the projected US federal deficit-to-GDP ratio leads to a 0.25% increase in long-term interest rates. Compared to this US estimate, the magnitude of the effect of budget deficits is much smaller in Japan. Despite its large budget deficits and outstanding debt, the Japanese government seems to be able to pursue fiscal expansion policies with relatively small crowding out effect.

Our estimation period includes the financial crisis of 2007-2008, but Japan's long-term interest rates were affected little by the event. In addition, recent political turmoil in the Middle East, Turkey, and Brazil has not significantly affected the long-term interest rates in Japan either, although these events are not included in our estimation period. These findings may suggest that the effect of budget deficits on long-term interest rates depend on economic structures and factors that have not been investigated in the previous studies. Future research can investigate this issue based on comparative analyses of different economies.

As is standard in the literature, we assumed throughout the analyses that the effect of budget deficits is constant over time. However, this assumption may be too restrictive. For example, agents may become gradually more sensitive to budget deficits as outstanding debt becomes larger and larger. In this case, the gradual switching model is potentially more powerful in capturing the true relationship. Future research can extend this important topic in this direction.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

1. Measures of Business Cycle

For the measure of business cycle conditions, we use relative output gap as compared to potential GDP:

$$\text{CYCLE} = \frac{\text{Actual GDP - Potential GDP}}{\text{Potential GDP}} \times 100 .$$

We estimate potential GDP using the production function approach due to Giorno et al. [44] and Cotis et al. [45]. The resulting two-factor Cobb-Douglas production function employed in this work is given by

$$\ln Y_t = \alpha \ln N_t + (1-\alpha)\ln K_t + \ln E_t$$

where Y = real GDP
N = employment
K = actual capital input
E = total factor productivity
α = average labor share.

Potential output is defined as the level of output when labor input is consistent with the non-accelerating inflation rate of unemployment (NAIRU) and when total factor productivity is at its trend level. That is, potential output is given by

$$\ln Y_t^* = \alpha \ln N_t^* + (1-\alpha)\ln K_t + \ln E_t^*$$

where Y^* = potential GDP
N^* = employment consistent with NAIRU
E^* = trend total factor productivity.

Actual capital input is computed by multiplying capital utilization rate to capital stock. Total factor productivity is computed as the Solow residual. Trend total factor productivity E_t^* and the NAIRU are derived by the Hodrick-Prescott filter. The Hodrick-Prescott filter is a smoothing method that is widely used among macroeconomists to obtain a smooth estimate of the long-term trend component of a series [46]. For many applications in the literature, λ is set to 1600 for quarterly data as originally chosen by Hodrick and Prescott [47]. We follow this convention in our derivation of E_t^* and N_t^*. The rational behind estimating the NAIRU by the Hodrick-Prescott filter is that actual unemployment can be considered as a mixture of the natural rate of unemployment N_t^* and demand shocks. Demand shocks are thought to exhibit more high-frequency variation than the natural rate and therefore the natural rate can be extracted by filtering method. To remove the effect of seasonality, we use smoothed seasonally adjusted labor force data. N_t^* is derived by multiplying one minus the NAIRU to the smoothed seasonally adjusted labor force.

2. Sources of Data

Labor force and unemployment data (seasonally adjusted) are taken from *the Labor Force Survey* administered by the Ministry of Internal Affairs and Communications. Average Labor share is calculated as dividing compensation of employees by national income. Data on GDP, GDP deflator, compensation of employees and national income are taken from *the Annual Report on National Accounts* (annual report on the System of National Accounts, 93SNA), compiled by the Cabinet Office. Actual capital input is computed by multiplying capital utilization rate to gross capital stock. Gross capital stock is taken from *the Annual Report on National Accounts*, and capital utilization rate is taken from *the Index of Capacity Utilization Rate* compiled by the Ministry of Economy, Trade and Industry.

Data on interest rates and consumer price index (CPI) are taken from IMF's *International Financial Statistics*. Short-term interest rate is measured by the money market rate, and long-term interest rate is measured by the government bond yield with 10-year maturity. Inflation is measured by year-to-year change in CPI, or $\ln P_t - \ln P_{t-4}$, where P_t is CPI.

Our measure of budget deficits is based on the difference between savings and investment of the general government, which is a consolidation of national and local governments plus social security fund. The figures are based on the System of National Accounts 1993 (SNA93) and are taken from *the Annual Report on National Accounts*. As a technical matter, we follow the usual convention and exclude the debt of the Japan National Railway Settlement Corporation and the National Forest Special Account when calculating budget deficits. Data on outstanding debt is taken from *the Annual Report on Government Bonds* administered by the Ministry of Finance.

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