

Budget Deficits and Long-Term Interest Rates in Japan

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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

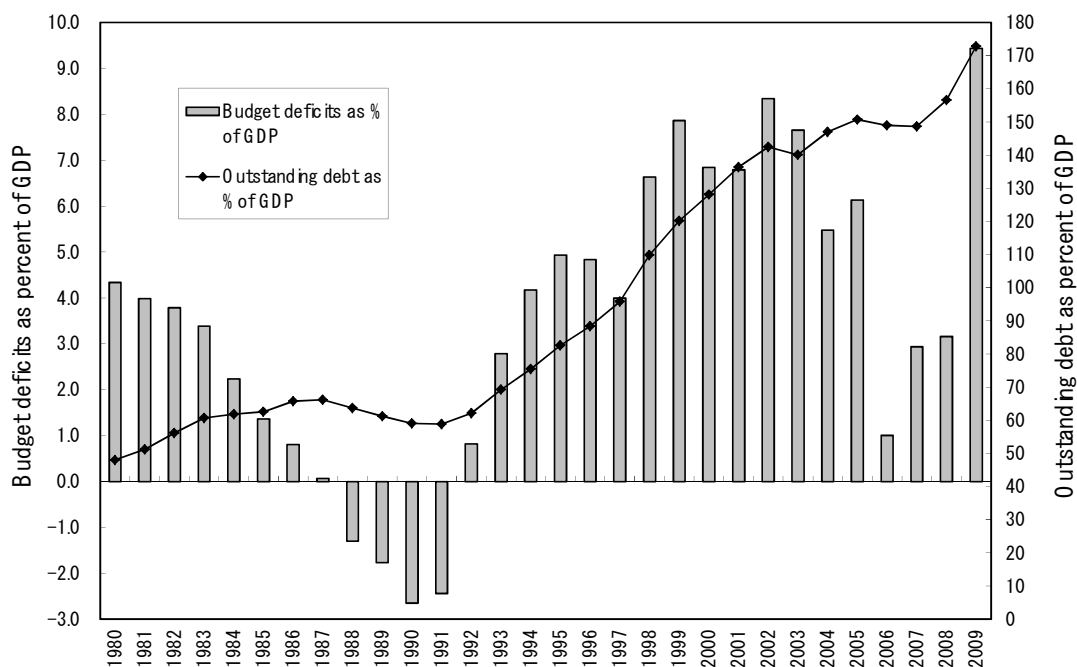
The effect of budget deficits on the economy is one of the most important unresolved issues in public economics and macroeconomics [1]. Although many economists believe that large budget deficits are harmful for the economy, there is considerable debate over their exact impact on prominent macroeconomic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

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40 United States; See Hoelscher [9], Feldstein [10], Cebula and Hung [11], Cebula and Rhodd
 41 [12], Reinhart and Sack [13], Cebula [14], Cebula [15], Laubach [16], Cebula and Cuellar
 42 [17]. Kiani [18] reported that the relationship becomes statistically significant only in the
 43 period after 1980, in which the financial market has become more reactive to expansions in
 44 fiscal expenditures with the emergence of large budget deficits.

45 Historically, fiscal position has been relatively in good standing in Japan. Outstanding long-
 46 term debt has been maintained below 60% of GDP during the 1970s and 1980s. However,
 47 the collapse of the bubble economy in the early 90s hampered this trend. As shown in Figure
 48 1, fiscal balance persistently deteriorated over the last two decades, due to expansionary
 49 fiscal policies coupled with a decline in tax revenues which are sensitive to business cycle
 50 fluctuations. Outstanding long-term debt has also expanded drastically from 59% of GDP in
 51 1991 to 136% of GDP in 2001 that escalated further to unprecedented over 170% of GDP in
 52 2009.



53 **Fig. 1. Budget deficits and outstanding debt as percent of GDP**
 54

55 *Note:* Negative values of budget deficits represent budget surplus.

56 *Source:* Authors' calculations based on the *Annual Report on National Accounts*, the
 57 Cabinet Office, and the *Annual Report on Government Bonds*, the Ministry of Finance.
 58

59 Despite seemingly critical fiscal situations of Japan, the literature on the relationship
 60 between budget deficits and interest rates focused on Japan is sparse. Among a few
 61 studies, Nakazato *et al.* [19] employed a simple OLS method and found insignificant effects
 62 of budget deficits and outstanding debt on nominal interest rates in Japan. Kameda [20]
 63 used budget projections officially published by the government and found a statistically
 64 significant relationship between projected budget deficits and long-term interest rates.

65 However, these studies do not adequately address time series properties of the dataset, and
66 the validity of their econometric analyses are questionable.

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

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

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

86

87 2. THEORETICAL MODEL

88

89 We employ a loanable funds model presented in Kiani [18], which is constructed based on
90 Sargent [21], Echols and Elliot [22], Hoelscher [9], Cebula and Hung [11], Cebula and Rhodd
91 [12]. Loanable funds model is also employed in some of the recent studies on this topic ([14],
92 [15], [17]).

93

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

$$97 \quad S_{LF} = a_1 + b_1 i^L + c_1 r^s + d_1 \pi^e + e_1 CYCLE + f_1 DEF \quad (1)$$

$$98 \quad D_{LF} = a_2 + b_2 i^L + c_2 r^s + d_2 \pi^e + e_2 CYCLE + f_2 DEF \quad (2)$$

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

102

103 In equation (1), the quantity of long-term supply for loanable funds should respond positively
104 to long-term interest rates ceteris paribus, and therefore we expect $b_1 > 0$. Higher values of
105 expected real short-term interest rates make short term loans relatively favorable among a
106 different choice of maturities and discourage lenders to lend long. Therefore, we expect its
107 coefficient to be negative ($c_1 < 0$). Higher inflation also reduces the willingness to lend long
108 because investors can invest in alternative debt instruments such as equities and real
109 estate, whose returns are less affected by high inflation. Therefore, we expect its coefficient
110 to be negative ($d_1 < 0$). An increase in economic activity increases the supply for long-term

111 funds and therefore its coefficient is expected to be positive ($e_1 > 0$). If the agents are
 112 sufficiently forward-looking, an increase in government debt causes rational agents to
 113 increase their savings in anticipation of future taxes, thereby increasing the supply of funds
 114 when budget deficits increase ($f_1 > 0$). In the case of myopic agents, the supply of funds is
 115 independent of budget deficits, and thus $f_1 = 0$.

116
 117 In equation (2), higher long-term interest rates reduce the demand for long-term borrowing,
 118 and therefore we expect a negative sign on its coefficient ($b_2 < 0$). An increase in short-
 119 term real interest rates causes borrowers to increase long-term borrowing ($c_2 > 0$)
 120 because long-term borrowing becomes relatively cheaper ceteris paribus. An increase in
 121 expected inflation reduces the cost of borrowing and therefore we expect $d_2 > 0$. Strong
 122 macroeconomic conditions raise the willingness to incur debt by firms and consumers, and
 123 therefore we expect $e_2 > 0$. Finally, the demand for funds increases with large budget
 124 deficits ceteris paribus due to expansions in fiscal expenditures ($f_2 > 0$).

125
 126 Solving equations (1) and (2) for the equilibrium long-term interest rate yields the following
 127 equation:

$$128 \quad i^L = \frac{(a_2 - a_1) + (c_2 - c_1)r^s + (d_2 - d_1)\pi^e + (e_2 - e_1)CYCLE + (f_2 - f_1)DEF}{(b_1 - b_2)} \quad (3)$$

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

$$131 \quad i_t^L = \beta_0 + \beta_1 r_t^s + \beta_2 \pi_t^e + \beta_3 DEF_t + \beta_4 CYCLE_t + u_t \quad (4)$$

132 where u_t is an error term. Comparing equations (3) and (4) by taking into account the
 133 above discussions, the signs of the coefficients in equation (4) are predicted to be as follows.
 134

135 The coefficients of ex-ante real short-term interest rates (r^s) and expected inflation (π^e) are
 136 expected to be positive. The effect of business cycle conditions (CYCLE) is ambiguous.
 137

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

146 $H_0: \beta_3 > 0$ (The traditional or Keynesian view)

147 $H_1: \beta_3 \leq 0$ (The Ricardian view).

148 While our primary focus is the effect of the deficit variable (β_3), the formulation also allows
 149 us to test whether the Fisher hypothesis holds for Japan. A strong form of the Fisher

¹ Studies by Evans [7] and Evans [8] reported counterintuitive findings that larger deficits reduce interest rates.

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.

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:

$$DEF_1 = \frac{\text{Budget deficit}}{\text{Nominal GDP}} \times 100.$$

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:

$$DEF_2 = \frac{\text{Budget deficit} - \pi D}{\text{Nominal GDP}} \times 100,$$

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

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.

191 inflation. Thus we subtract πD from nominal deficits to construct a real measure of budget
 192 deficits.

193

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

212

213 After these manipulations, we have usable quarterly data of all variables from the second
 214 quarter of 1981 to the first quarter of 2009.

215

216 4. TIME SERIES PROPERTIES AND ESTIMATION

217

218 4.1 Unit root tests

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

230

231 **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 Kwiatkowski, 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 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.

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
$r \leq 1$	$r > 1$	34.901	0.0537	30.855	0.1363
$r \leq 2$	$r > 2$	14.127	0.2808	13.622	0.3162
λ_{max} tests		λ_{max} value		λ_{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 λ_{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.

We estimated the characteristic roots and calculated λ_{trace} and λ_{max} test statistics, where λ_{trace} is the trace statistic and λ_{max} is the maximum eigenvalue statistic. The results are shown in Table 2. For the variable DEF_1, both λ_{trace} and λ_{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 λ_{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 λ_{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.

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 (Stock and Watson [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)

	Johansen ML	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)***
$r_t^s (\beta_1)$	0.6850 (0.0515)***	0.6386 (0.0479)***	0.8330 (0.0512)***	0.8177 (0.0496)***	0.8353 (0.0666)***	0.8143 (0.0675)***
$\pi_t^e (\beta_2)$	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:

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

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

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 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 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 was 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.

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.

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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:

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

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 (Reeves *et al.* [46]). For many applications in the literature, λ is set to 1600 for quarterly data as originally chosen by Hodrick and Prescott (Hodrick and Prescott [47]). We follow this convention in our derivation of E_t^* and N_t^* . The rationale 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.

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2. Sources of data

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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.

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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.

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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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