

Fiscal Discipline and Sustainability of Public Debt: An Empirical Analysis using Japanese Long-term Economic Statistics *

Takeshi Kudo †

Abstract

In this paper, we employ Japanese Long-term Economic Statistics (LTES) to investigate the sustainability of the public debt, and the changes in fiscal discipline. First, the results of the unit-root test show that public debt in Japan is sustainable. Second, fiscal discipline was strong in the periods between the Russo-Japanese War and the First World War, as well as for several decades after the Second World War. It was also relatively strong during the fiscal consolidation period in the latter half of the 1980s. We can thus conclude that the path of post-war fiscal discipline in Japan is similar to that in the pre-war periods, regardless of the absence of war expenses after World War II. Although an attempt at fiscal consolidation could reduce public debt to some degree, the huge amount of current public debt will cause high rates of inflation in the future, as it did after World War I and World War II.

Key words: Sustainability of public debt, Fiscal discipline, Markov-switching regressions

1 Introduction

Tax reductions and increase in public expenditure during the long-term stagnation since the 1990s have resulted in the accumulated public debt reaching 160% of Japan's GNI (Gross National Income) in 2008. People worry about the increasing debt because there has been a decrease in labor power as a result of the falling birth rate and the aging society.

The Japanese economy has often experienced rapid debt accumulation. After the Russo-Japanese War (1904-1905), the government needed to finance huge war expenses, and it issued large amounts of government bonds. Other examples of such long-term war expenses, include the Second Sino-Japanese War, and the Pacific Ocean War that took place between 1937 to 1945 (See Figure 1 and Figure 2).

Each example mentioned above involved different adjustment processes in

* This work was supported by Grant-in-Aid for Young Scientists (B) No.20730185.

† Faculty of Economics of Nagasaki University, Katafuchi 4-2-1, Nagasaki-shi, Nagasaki, Japan. Tel. & Fax: +81-95-820-6369, E-mail: tkudo@nagasaki-u.ac.jp

regard to public debt. The public debt associated with the expenses of the Russo-Japanese War was resolved by the fiscal surpluses after the war, while the debt that accumulated between 1937 and 1945 was reduced by hyperinflation after the war (See Figure 3 and Figure 5).

Our analysis considers the following aspects. First, we verify the sustainability of public debt in Japan using Long-term Economic Statistics (LTES) from the 1880s. Ahmed and Rogers (1995) use long-term data in the U.S. and the UK to examine the sustainability of public debt, and concludes that the debt is sustainable in those countries. In Japan, research using long-term historical data is rare, although Broda and Weinstein (2005), Doi et al. (2005), and Iwamura et al. (2006) used data from the post-war period.¹

Second, we will implement the Markov-switching regression, to consider the possibility of structural breaks in the long-term data. From a historical perspective, Okazaki (2004) shows that fiscal discipline has been relaxed since the end of 1920s. We will investigate whether this structural change can be observed in the actual data.

In addition to the empirical issues just mentioned, tests with structural breaks are important, as stated below. Sustainability is defined as the case in which the *ex post* inter-temporal budget constraint is satisfied. This definition allows a reduction in the value of debt, as a result of the hyperinflation associated with fiscal collapse.² Therefore, those tests that allow structural breaks enable us to investigate the sustainability of public debt, even in the case in which the sustainability condition is temporarily not satisfied.

The rest of the paper is organized as follows. Section 2 examines the conditions for fiscal sustainability, by reviewing related research. Section 3 implements some tests for the sustainability of public debt, using Long-term Economic Statistics (LTES) in Japan, based on the methods reviewed in the previous section. Section 4 discusses fiscal discipline in Japan along with the results in the previous section. Section 5 concludes the paper.

2 Testing the Sustainability of Public Debt

2.1 Testing Sustainability with a Linear Model

In this paper, we employ the methods that have been developed to test the sustainability of public debt. These methods were developed by Hamilton and Flavin (1986). Trehan and Walsh (1991) expanded these methods to the case in which market discount rates are variable. The necessary condition for the sustainability of public debt is the cointegration of tax revenue, government

¹ Doi et al. (2005) and Iwamura et al. (2006) conclude that the public debt is not sustainable, while Broda and

Weinstein (2005) simulate some cases using the data, and conclude that the debt is sustainable.

² Leeper (1991) calls this situation an “active” fiscal policy, and Woodford (1995) subsequently defines it as a

“Non-Ricardian” fiscal policy.

expenditure, and the interest on public debt; and the sufficient condition is the stationarity of public debt. In this sense, Trehan and Walsh (1991) test the necessary and sufficient conditions, and conclude that the U.S. public debt is sustainable.

Bohn (1995) and Ahmed and Rogers (1995) use the necessary and sufficient condition that tax revenue, government expenditure, and interest on public debt have a cointegration vector, and that this cointegration vector satisfies a constraint, and conclude that public debt in the U.S. and in the UK is sustainable.

We obtain the condition for the sustainability of public debt from the budget constraint of the government. First, the flow budget constraint in period t is given as

$$(1) \quad D_t - D_{t-1} = G_t - T_t + r_t D_{t-1} = -s_t,$$

where D_t is the level of public debt, G_t is government expenditure, T_t is tax revenue, $r_t D_{t-1}$ is the interest on public debt, and s_t is the fiscal surplus. The

stochastic discount factor is defined as $Q_{t,t+k} = \left[\beta^k \frac{u'(C_{t+k})}{u'(C_t)} \right]$, where β is the subjective discount factor, C_t is the consumption level at period t , $u(\cdot)$ is the utility function that satisfies the condition $u'(\cdot) > 0$ and $u''(\cdot) < 0$. The Euler condition for inter-temporal substitution of consumption satisfies

$$(2) \quad E_t \left[\prod_{j=0}^k Q_{t,t+j} \right] = 1.$$

Solving equation (1), and substituting equation (2) into the budget constraint, we obtain the inter-temporal budget constraint as

$$(3) \quad E_t \sum_{k=0}^{\infty} Q_{t,t+k} G_{t+k} - E_t \sum_{k=0}^{\infty} Q_{t,t+k} T_{t+k} + (1 + r_t) D_{t-1} = \lim_{K \rightarrow \infty} E_t Q_{t,t+K} D_{t+K}.$$

We will show the condition for the sustainability of public debt. If the transversality condition for this system, $\lim_{K \rightarrow \infty} E_t Q_{t,t+K} D_{t+K} = 0$, is satisfied, we obtain that

$$(4) \quad (1 + r_t) D_{t-1} = E_t \sum_{k=0}^{\infty} Q_{t,t+k} (G_t - T_t).$$

This means that the level of public debt at the beginning must be equal to the present value of government's net revenue at present and in the future, if the present value of public debt at the terminal is to converge to zero: that is, if it is to satisfy the transversality condition.

Ahmed and Rogers (1995) transform equation (3) to derive the necessary and sufficient condition for the sustainability of public debt. Differencing and arranging equation (3), we obtain that

$$(5) \quad \Delta E_t \sum_{k=0}^{\infty} Q_{t,t+k} G_{t+k} - \Delta E_t \sum_{k=0}^{\infty} Q_{t,t+k} T_{t+k} + (G_t - T_t + r_t D_{t-1}) = \lim_{K \rightarrow \infty} E_t Q_{t,t+K} D_{t+K} - \lim_{K \rightarrow \infty} E_{t-1} D_{t-1},$$

where Δ is the difference operator.

Ahmed and Rogers (1995) show that the necessary and sufficient condition for the sustainability of public debt is that government expenditure, tax revenue, and interest on public debt have the cointegration vector $(1, -1, 1)$. This constraint on

the cointegration vector means the fiscal deficit $-s_t$ in the equation (1).

Therefore, we can verify the sustainability of public debt by testing the stationarity of the fiscal deficit $-s_t$. This test is usually implemented as a unit-root test for

$$(6) \quad \Delta s_t = \mu + \lambda s_{t-1} + \varepsilon_t,$$

where the null hypothesis is $\lambda = 0$.

2.2 Structural Breaks and Sustainability

In the case in which the true model is not linear, as in equation (6), unit-root tests did not function because of a formulation error.

Raybaudi et al. (2004) employ a non-linear model with structural breaks between stationary and non-stationary regimes, to test the sustainability of current account deficits, by estimating the Markov-switching regression as

$$(7) \quad \text{Stationary regime } (\theta_t = 0) : \Delta s_t = \mu_0 + \lambda s_{t-1} + \sigma \varepsilon_t.$$

$$(8) \quad \text{Non stationary regime } (\theta_t = 1) : \Delta s_t = \mu_1 + \sigma \varepsilon_t.$$

Combining these equations, we obtain

$$(9) \quad \Delta s_t = [\mu_0(1 - \theta_t) + \mu_1\theta_t] + \lambda(1 - \theta_t)s_{t-1} + \sigma \varepsilon_t,$$

where the coefficient λ satisfies $-2 < \lambda < 0$, and ε_t is the disturbance term which follows the white-noise process. The state variable θ_t follows the first-order Markov chain $\theta \in \Theta = \{0, 1\}$, and the transition probability

$$p_{ij} = P\{\theta_{1t} = j \mid \theta_{1(t-1)} = i\} \text{ satisfies that } p_{ij} \in [0, 1] \text{ and } \sum_j p_{ij} = 1.$$

The Markov-switching model is estimated by the maximum likelihood method, assuming that the conditional probability density, given the observed and state variables till period t , is Gaussian. If $\theta_t = 1$ in equation (9), then the process of s_t follows equation (8), and it can be concluded that it is locally non-stationary. However, this does not mean global non-stationarity. Francq and Zakoian (2001) define the necessary and sufficient condition for second-order stationarity as

$$(10) \quad x = p_{00}\rho^2 + p_{11} + (1 - p_{00} - p_{11})\rho^2 < 1,$$

$$(11) \quad y = p_{00}\rho^2 + p_{11} < 2,$$

where $\rho = 1 + \lambda$.

3 An Empirical Analysis with Japanese Long-term Economic Statistics (LTES)

In this section, we test the sustainability and structural break of the public debt using long-term economic statistics (LTES) in Japan. First, we explain the data used in our analysis. Second, we test the sustainability of public debt with a linear model, by employing the unit-root test. Third, we test the sustainability with a structural break, by estimating the Markov-switching model. Finally, we discuss fiscal discipline in Japan in the context of the long-term historical data.

3.1 Data

The data on fiscal surplus that is used in our analysis is calculated from the SNA data. Public saving is S_t^g , public capital formation is I_t^g , and net interest payments are used in this calculation as

$$s_t = T_t - G_t - r_t D_{t-1} = S_t^g - I_t^g + r_t D_{t-1},$$

and all the data is divided by GNI.

We used annual data from 1885 to 2007. The data are collected from Ohkawa and Shinohara (1979), Japan Statistical Association (1988), and the Cabinet Office of Japan. We used a series of interest payments on government bonds until 1954 from the “Annual Reports on Government Bond Statistics,” because the series of property income in the SNA data was not available for this period.

In our data, level shifts may occur in the periods between 1940 and 1941 when the data estimated by Ohkawa and Shinohara (1979) are chained to the data estimated by Japan Statistical Association (1988), between 1954 and 1955 when the data are chained to 68SNA, and between 1979 and 1980 when the data are chained to 93SNA. However, useful information for testing for a structural break may be lost by a priori data correction for the level shifts. For this reason, we do not correct the data before the analysis.

The series of fiscal surpluses is shown in Figure 3. The shaded areas indicate wartime periods: the first Sino-Japanese War from 1894 to 1895, the Russo-Japanese War from 1903 to 1907, the European War (First World War), including the Siberian Intervention, from 1914 to 1920, and the Second Sino-Japanese War, and the Pacific Ocean War (Second World War) from 1937 to 1945.³ The fiscal surplus tends to decline in wartime, but, on the other hand, it improved rapidly after the Russo-Japanese War and the Pacific Ocean War.

The descriptive statistics of the fiscal surplus and its components (public saving, public investment, and interest on debt) are shown in Table 1. The fiscal surplus records its minimum in 1944, and its maximum in 1949. The difference between its mean and its median is larger than 1%, and the normality of the data is rejected by the Jarque-Bera test.

3.2 Empirical Results with a Linear Model

We apply the unit-root test to the series of fiscal surpluses explained above, to examine whether public debt in Japan is sustainable. First, we apply the unit-root test for each component of fiscal surplus (public savings S_t^g , public investments I_t^g , and the interest on public debt $r_t D_{t-1}$) as the preliminary analysis, because, to apply the method by Ahmed and Rogers (1995), it is necessary that these series follow the first-order integrated process.

The results of the test for the sustainability of the public debt are shown in Table 2. The unit-roots are not rejected for the levels of all variables. The unit-roots are rejected for the first differenced variables of public investment I_t^g and interest on public debt $r_t D_{t-1}$, so we can conclude that these variables follow the first-order integrated processes. For public savings S_t^g , the result is ambiguous. The unit-root is not rejected by the Augmented Dickey-Fuller (ADF) test, but it is rejected at the 10% significant level by the Dickey-Fuller (DF) GLS test, which

³ These periods do not necessarily correspond to the actual war days, because these periods are defined as the fiscal years in which the Extraordinary Special Accounts for War Expenses were planned and implemented by the government.

has a greater testing power than the ADF test.

The results of the test for the sustainability of public debt with a linear model are shown in Table 3. The unit-root for the level of fiscal surplus is rejected at the 10% significant level by the ADF and DF-GLS tests. Therefore, we can conclude that the Japanese public debt is sustainable at the 10% significant level for the entire sample period from 1885 to 2007.

3.3 Empirical Results from a Markov Switching Model

We apply the Markov-switching regression model to the series of fiscal surpluses to test the sustainability of, and the structural change in, fiscal conditions in Japan. In the next section, we will focus on the probability that the series are stationary in each period, in order to examine whether the government exhibits strong fiscal discipline in that period.

The result of the Markov-switching regression is shown in Table 4. First, all the parameters are estimated significantly in this model. Then, we test the second-order stationarity for the fiscal surplus, based on equations (10) and (11). These conditions are satisfied in our result, shown in Table 4. So, we conclude that the public debt is sustainable in the second-order.⁴

4 Fiscal Discipline with Japanese Long-term Economic Statistics

4.1 Wars and Fiscal Discipline before World War II

Figure 4 shows the probability that the series of fiscal surpluses are in the stationary regime derived from the estimates of the model in equation (9). We can interpret the results shown in Figure 4 as below.

First, the fiscal discipline indicated by the graph in Figure 4 was relaxed, from after the First Sino-Japanese War in 1894 till the end of the Russo-Japanese War in 1905. This result corresponds to the increase in fiscal deficits in that period, in Figure 3, due to military expenses for wars, and some military action against China. The level of public debt did not rise in this period, because of the huge amount of compensation received from China after the First Sino-Japanese War.

Second, from Figure 4 we were able to observe that fiscal discipline tightened rapidly after the Russo-Japanese War. Fiscal surpluses were recorded for a decade. In this situation, a huge amount of government bonds had to be issued to finance the war expenses of the Russo-Japanese War, and they were sold to foreigners through the London market, because such a huge amount of bonds could not have been sold in the domestic market in Japan. For another reason, Japan was not compensated by Russia after the war. In addition, the balance of payments was constrained, because the gold standard was adopted. The huge amount of government bonds owned by foreigners may then have resulted in disciplined fiscal management. The level of public debt was reduced from 69% of GNI in 1905 to 53% in 1915, by the effort at fiscal consolidation, and the debt was then reduced to 23% of GNI in 1919, by the high inflation rates during the First

⁴ Note that this result is not derived from the formulated testing process, because x , y do not follow typical probability distributions.

World War.

Third, fiscal discipline was rapidly relaxed after World War I, as shown in Figure 4. Okazaki (2004) shows that party politics in the 1920s, and military power in the 1930s, increased government expenditure, because of the decentralized political system, and the absence of political power after the retirements of elder statesmen with extensive power. In addition, the real value of the public debt was reduced by inflation during World War I. (See Figure 1 and Figure 5.)⁵

Then, fiscal deficits were increased by the economic crisis at the end of the 1920s, and by the increase in military expenditure caused by the Second Sino-Japanese War and the Pacific Ocean War, from the mid-1930s onwards. In that period, fiscal discipline collapsed completely. Therefore, the public debt soared and caused hyper-inflation after the war, as shown in Figure 5.

4.2 Fiscal Discipline after the World War II in Japan

In the long run, Japan has enjoyed economic prosperity without war. As shown in Figure 2, military expenses are not the main cause of fiscal deficits. Has this change influenced fiscal discipline?

Fiscal balance was maintained until the beginning of the 1970s, although this success is partly attributable to the increase in tax revenue because of rapid growth. Fiscal discipline was maintained in this period. In the beginning of the 1970s, the government issued bonds because of the serious recession caused by the oil shocks and the end of rapid growth, and fiscal discipline then deteriorated until the middle 1980s (see Figure 4). In this period, the level of public debt rose from 12% of GNI in 1973 to 56% in 1987.

In the latter half of the 1980s, an effort at fiscal consolidation, and an increase in tax revenue because of economic expansion, led to a revival in fiscal discipline, and in 1991 public debt was reduced to 48% of GNI. However, this revival was temporary because of the increase in fiscal deficits after the collapse of the “bubble economy” in 1991. Public debt has been soaring for two decades, and in 2008 it finally reached 161% of GNI.

Ironically, the absence of huge war expenses, the paths of public debt in Figure 1, and fiscal discipline in Figure 4, after World War II, all resemble the conditions before the War. The present accumulation of public debt is as serious as that in the pre-war period, although the Japanese people now hold a huge amount of financial assets (about 250% of GNI).

5 Conclusion

In this paper, we employ Japanese Long-term Economic Statistics (LTES) to investigate the sustainability of the public debt and the changes in fiscal discipline. We obtain the results set out below.

First, we implement the Augmented Dickey-Fuller and the Dickey-Fuller GLS tests to examine the sustainability of public debt, with a linear model. The result

⁵ Note that public debt in Figure 1 is defined as the horizon of central government, whereas we analyze the fiscal surplus of general government.

implies that the public debt is sustainable at the 10% significant level.

Second, we estimate the Markov-switching regression model, to investigate the sustainability of public debt with a structural break. This analysis implies the second-order stationarity of the fiscal surplus. We can conclude that the public debt is also sustainable from this perspective.

Then, we apply the estimates of the Markov-switching regression to examine whether the government has maintained a strong fiscal discipline in that period, by focusing on the probability that the series of fiscal surplus are in the stationary regime.

The results imply that fiscal discipline was strong in the periods between the Russo-Japanese War and the First World War, and for several decades after the Second World War, and that fiscal discipline was relatively strong during the fiscal consolidation in the latter half of the 1980s. We can conclude that the path of post-war fiscal discipline in Japan is similar to that in pre-war periods, despite the absence of war expenses after World War II.

Although an effort at fiscal consolidation could reduce the public debt to some degree, such a large amount of public debt would cause high rates of inflation in the future, as it did after World War I and World War II.

References

- [1] Ahmed,S., and J.H.Rogers, (1995), "Government Budget Deficits and Trade Deficits: Are Present Value Constraints Sustained in Long-term Data?", *Journal of Monetary Economics* 36, pp.351–374.
- [2] Bohn,H., (1995), "The Sustainability of Budget Deficits in a Stochastic Economy," *Journal of Money, Credit and Banking* 27, pp.257–271.
- [3] Broda, C., and D.E. Weinstein, (2005), "Happy News from the Dismal Science: Reassessing Japanese Fiscal Sustainability," Chapter 2 in Ito,T, H.Patrick, and D.Weinstein(eds.), *Reviving Japan's Economy: Problems and Prescriptions*, MIT Press.
- [4] Doi,T., T.Ihori, and K.Mitsui, (2005), "Sustainability, Debt Management, and Public Debt Policy in Japan," NBER Working Paper 12357.
- [5] Francq,C., and J.-M.Zakoian, (2001), "Stationarity of Multivariate Markov-switching ARMA Models," *Journal of Econometrics* 102, pp.339–364.
- [6] Hamilton,J.D., (1994), *Time Series Analysis*, Princeton University Press.
- [7] Hamilton,J.D., and M.A.Flavin, (1986), "On the Limitations of Government Borrowing: A Framework for Empirical Testing," *American Economic Review* 76, pp.808–819.
- [8] Iwamura,M., T.Kudo, and T.Watanabe, (2006), "Monetary and Fiscal Policy in a Liquidity Trap: The Japanese Experience 1999-2004," Chapter 6 in Ito, T., and A.Rose (eds.) *Monetary Policy with Very Low Inflation in the Pacific Rim*, Chicago University Press, Chicago.
- [9] Japan Statistical Association (eds.), (1988), *Historical Statistics of Japan*, Japan Statistical Association.
- [10] Leeper,E.M., (1991), "Equilibria under 'Active' and 'Passive' Monetary and Fiscal Policies," *Journal of Monetary Economics* 27, pp.129–147.
- [11] Ohkawa,K., and M.Shinohara (eds.), (1979), *Patterns of Japanese*

Economic Development, Yale University Press, New Haven. (Printed in Japanese as Ohkawa,K., M.Shinohara, and M.Umemura (eds.), (1966), *Estimates of Long-term Economic Statistics of Japan since 1868* Book1–13, Toyo Keizai Shimposha.)

- [12] Okazaki,T., (2004), "Political System and Fiscal Performance: Japan's Historical Experiences (in Japanese)," RIETI Discussion Paper 04-J-009.
- [13] Raybaudi,M., M.Sola, and R.Spagnolo, (2004), "Red Signals: Current Account Deficits and Sustainability," *Economics Letters* 84, pp.217–223.
- [14] Shimbo,H., (1978), *Prices and Economic Development in Early Modern Period in Japan* (in Japanese), Toyo Keizai Shimposha.
- [15] Trehan,B., and C.E.Walsh, (1991), "Testing Intertemporal Budget Constraints: Theory and Applications to U.S. Federal Budget and Current Account Deficits," *Journal of Money, Credit and Banking* 23, pp.206–223.
- [16] Woodford,M., (1995), "Price-Level Determinacy without Control of a Monetary Aggregate," *Carnegie-Rochester Conference Series on Public Policy* 43, pp.1–46.

Table 1: Descriptive Statistics

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Jarque-Bera
Public Savings	3.150	4.026	16.351 [1949]	-20.737 [1944]	5.179	348.1 (.000)
Public Investments	5.384	5.084	15.322 [1938]	2.200 [1887]	2.148	358.8 (.000)
Interest on Debt (net)	1.273	1.195	3.949 [1944]	-0.389 [1965]	0.984	2.436 (.296)
Fiscal Surplus	-2.230	-0.907	9.449 [1949]	-24.065 [1944]	5.170	136.3 (.000)

1) Figures in brackets mean the year that the values recorded maximum (or minimum).

2) Values in parentheses mean P-values of the Jarque-Bera test statistics.

Data Sources)

- 1885–1940: Ohkawa and Shinohara (1979)
- 1941–1955: Japan Statistical Association (1988)
- 1955–1979: Cabinet Office, *National Accounts for 1998*.
- 1980–2007: Cabinet Office, *National Accounts for 2007: Including Retroactive Results from 1980*.

Table 2: Results of Unit-root Tests

Variables		Levels		1st differences			
		ADF	DF-GLS	ADF	DF-GLS		
Public Savings	Test Stat.	-0.077	-0.275	-1.868	-1.749	*	
	Lag Length	12	12	12	7		
Public Investments	Test Stat.	-2.365	-0.973	-3.975	***	-2.021	**
	Lag Length	7	7	12	6		
Interest on Debt	Test Stat.	-0.609	-0.394	-3.824	***	-3.179	***
	Lag Length	2	0	12	12		

1) “ADF” means the Augmented Dickey-Fuller test, and “DF-GLS” means Dickey-Fuller GLS test by Elliott, Rothenberg, and Stock.

2) Lag lengths in the unit-root tests are chosen by the Schwarz Bayesian information criterion.

3) “***” (or “**”, “*”) means that the null-hypothesis of unit-root is rejected at 1% (or 5%, 10%) significant level.

Table 3: Tests for Sustainability of Public Debt with a Linear Model

	Levels		1st differences	
	ADF	DF-GLS	ADF	DF-GLS
Test Stat.	-2.721 *	-1.903 *	-3.531 ***	-3.230 ***
Lag Length	12	12	12	12

- 1) These tests are implemented as unit-root tests on “Fiscal Surplus” in Table 1 for the period 1885–2007.
- 2) “ADF” means the Augmented Dickey-Fuller test, and “DF-GLS” means Dickey-Fuller GLS test by Elliott, Rothenberg, and Stock.
- 3) Lag lengths in the unit-root tests are chosen by the Schwarz Bayesian information criterion.
- 4) “***” (or “**”, “*”) means that the null-hypothesis of unit-root is rejected at 1% (or 5%, 10%) significant level.

Table 4: Estimation Results of the Markov-switching Regression

Variable	μ_0	μ_1	λ	σ
Estimates	1.111 **	-0.490 **	-0.586 ***	1.918 ***
Std. Errors	(0.445)	(0.211)	(0.059)	(0.125)
Variable	ρ_{00}	ρ_{11}	ρ_{01}	ρ_{10}
Estimates	-2.355 **	-3.199 ***	0.913	0.961
Std. Errors	(1.040)	(0.680)		
Variable	x	y	Log likelihood	
Estimates	0.968	1.117	-259.7	

- 1) The Markov-switching regression between two regimes is defined as

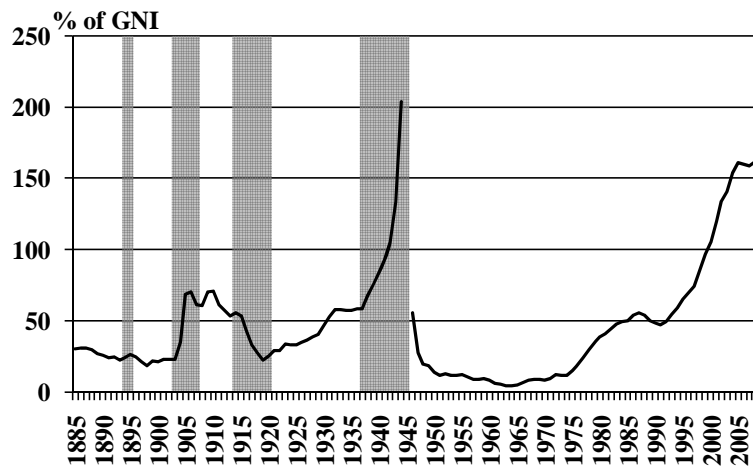
$$\Delta s_t = \mu_0 + \lambda s_{t-1} + \varepsilon_t$$
 in the stationary regime,

$$\Delta s_t = \mu_1 + \varepsilon_t$$
 in the non stationary regime,
 where s_t is fiscal surplus and ε_t is the disturbance term, which follows a white-noise process.
- 2) $\rho_{100} = P(\theta_{1t} = 0 | \theta_{1(t-1)} = 0)$ and $\rho_{111} = P(\theta_{1t} = 1 | \theta_{1(t-1)} = 1)$, where $\theta_{1t} = 0$ means the fiscal surplus is in the stationary regime and $\theta_{1t} = 1$ means it is in the non-stationary regime.

$$\rho_{00} = \frac{1}{(1 + \exp(\rho_{00}^*))}, \rho_{11} = \frac{1}{(1 + \exp(\rho_{11}^*))}$$
- 3) ρ_{00}, ρ_{11} are calculated by
- 4) Values in parentheses mean standard errors of estimates.
- 5) The second order conditions for stationarity are defined as $x < 1$ and $y < 2$, where

$$x = \rho_{00}\rho^2 + \rho_{11} + (1 - \rho_{00} - \rho_{11})\rho^2, y = \rho_{00}\rho^2 + \rho_{11}$$
 and $\rho = 1 + \lambda$.
- 6) “***” (or “**”, “*”) means that the null-hypothesis of unit-root is rejected at the 1% (or 5%, 10%) significant level.

Figure 1: Public Debt (Central Government) in Japan

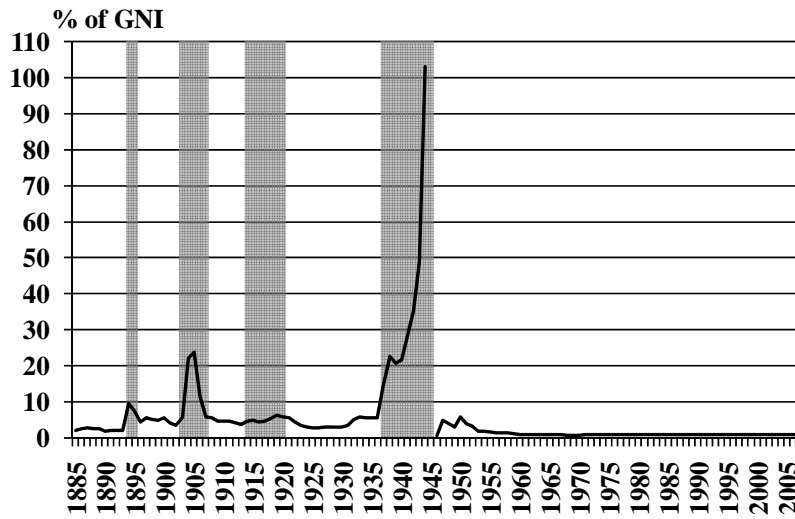


1) The shaded areas indicate wartime periods. These are the First Sino-Japanese War (1894–1895), the Russo-Japanese War (1903–1907), the First World War, including the Siberian Intervention, (1914–1920), and the Second Sino-Japanese War and the Pacific Ocean War (1937–1945). These periods are defined as the fiscal years in which the Extraordinary Special Accounts for War Expenses were implemented by the government.

Data Sources)

- 1885–2002: Statistics Bureau, Ministry of Internal Affairs and Communications, *Historical Statistics of Japan*, Table 5–9.
- 2003–2007: Ministry of Finance

Figure 2: National Defense and War Expenses in Japan

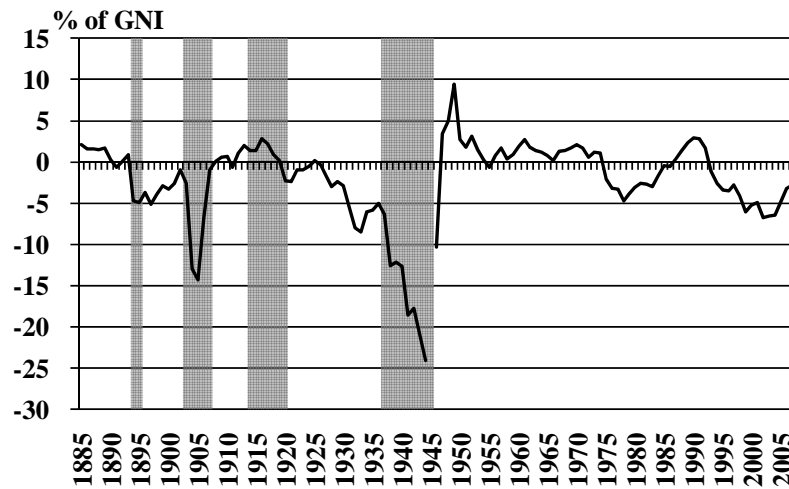


1) The shaded areas indicate wartime periods. These are the First Sino-Japanese War (1894–1895), the Russo-Japanese War (1903–1907), the First World War including the Siberian Intervention (1914–1920), and the Second Sino-Japanese War and the Pacific Ocean War (1937–1945). These periods are defined as the fiscal years in which the Extraordinary Special Accounts for War Expenses were implemented by the government.

Data Sources)

- 1885–1949: Ohkawa and Shinohara (1979)
- 1950–2005: Statistics Bureau, Ministry of Internal Affairs and Communications, *Historical Statistics of Japan*, Table 31-1.
- 2006–2007: Ministry of Finance

Figure 3: Fiscal Surpluses (General Government) in Japan

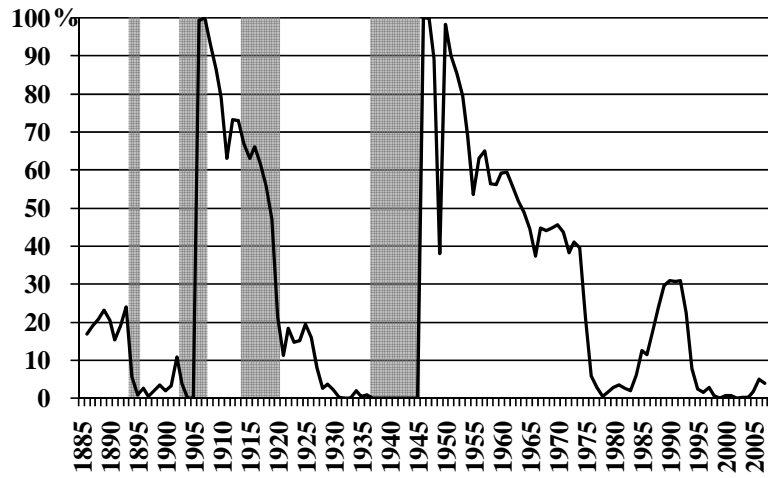


1) The shaded areas indicate wartime periods. These are the First Sino-Japanese War (1894–1895), the Russo-Japanese War (1903–1907), the First World War, including the Siberian Intervention (1914–1920), and the Second Sino-Japanese War and the Pacific Ocean War (1937–1945). These periods are defined as the fiscal years in which the Extraordinary Special Accounts for War Expenses were implemented by the government.

Data Sources)

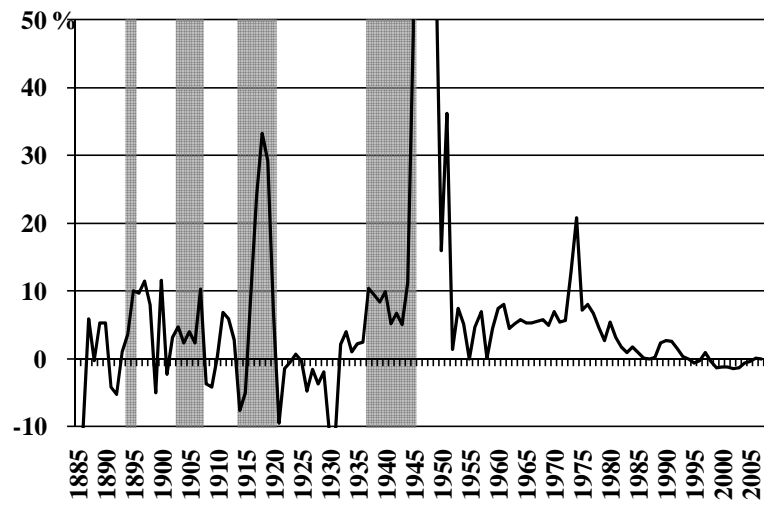
- 1885–1940: Ohkawa and Shinohara (1979)
- 1941–1955: Japan Statistical Association (1988)
- 1955–1979: Cabinet Office, *National Accounts for 1998*.
- 1980–2007: Cabinet Office, *National Accounts for 2007: Including Retroactive Results from 1980*.

Figure 4: Probability of Stationary (Sustainable) Regime



- 1) This figure is drawn using the results shown in Table 4.
- 2) The shaded areas indicate wartime periods. These are the First Sino-Japanese War (1894–1895), the Russo-Japanese War (1903–1907), the First World War, including the Siberian Intervention (1914–1920), and the Second Sino-Japanese War and the Pacific Ocean War (1937–1945). These periods are defined as the fiscal years in which the Extraordinary Special Accounts for War Expenses were implemented by the government.

Figure 5: Inflation Rates of GNI Deflator in Japan



1) The shaded areas indicate wartime periods. These are the First Sino-Japanese War (1894–1895), the Russo-Japanese War (1903–1907), the First World War, including the Siberian Intervention (1914–1920), and the Second Sino-Japanese War and the Pacific Ocean War (1937–1945). These periods are defined as the fiscal years in which the Extraordinary Special Accounts for War Expenses were implemented by the government.

2) After the Pacific Ocean War, “hyperinflation” occurred in Japan: the records show 48.2% in 1945, 355.8% in 1946, 190.4% in 1947, 160.6% in 1948, and 60.2% in 1949.

Data Sources)

- 1885–1955: Simbo (1978) and Ohkawa and Shinohara (1979).
- 1955–1979: Cabinet Office, *National Accounts for 1998*.
- 1980–2007: Cabinet Office, *National Accounts for 2007: Including Retroactive Results from 1980*.