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Testing Fisher Hypothesis from Japanese Interest Rate Swap Market

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SUMMARY

This paper investigates the validity of the Fisher hypothesis from the Japanese interest rate swap market by using non-stationary time series models. The data used for the analysis are confirmed to be $I(1)$ by unit root tests. From the tests of cointegration and cointegration vector, I can conclude that the Fisher hypothesis doesn't hold in the long term interest rates of 2 years, 3 years, 4 years, 5 years, 7 years and 10 years from October 1987 through June 2006. This result isn't surprising since the sample period includes deflationary period when inflation rates were negative and the nominal interest rates decreased to historical low level.

JEL Classification : E44, G10

Keywords : Fisher Hypothesis, Japanese Interest Rate Swap, Cointegration

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1. Introduction

Fisher (1930) maintains that the expected rate of inflation is reflected in the nominal interest rates and the real interest rates are constant. This relationship between the expected rate of inflation and the nominal interest rates is called Fisher hypothesis. This paper tests the validity of the Fisher hypothesis by using the Japanese interest rate swap market. The market for interest rate swaps has grown exponentially in the 1990's. According to a survey by BIS (Bank for International Settlements), the notional outstanding volume of transactions of interest rate swaps amounted to 229,780 billions of US dollars at the end of December 2006. [1]

The data used in this paper is likely to contain a non-stationary process called unit root. However when the non-stationary variables are included, ordinary hypothesis test tends to draw mistaken results since the coefficient of determination and t-statistics don't follow a simple distribution. Granger and Newbold (1974) call this problem 'Spurious Regression'. Phillips (1986) indicates two points as to the analysis of non-stationary data — (1) the coefficient of determination tend not to measure a relationship among variables, (2) estimated equation with low Durbin-Watson ratio can possibly have a problem of spurious regression. Non-stationary time series model is used to cope with a problem of unit root.

There are no unified conclusions as to the analysis of Fisher hypothesis [2]. The conclusions are different depending on countries, periods, and interest rates. As for the previous studies analyzing Fisher hypothesis, Atkins (1989), Atkins and Chan (2004), Berument (1999), Berument and Jelassi (2002), Berument et al (2007), Bonham (1991), Carneiro et al (2002), Granville and Mallick (2004), Inder and Silvapulle (1993), MacDonald and Murphy (1989), Mishkin (1992), Moosa and Kwiecien (2002), Payne and Ewing (1997), Yu (1997), Wallace and Warner (1993), Woodward (1992), Wong and Wu (2003), Kamae (1999) and Ito (2003) are cited.

Atkins (1989) conducts Engle and Granger cointegraion test by using CPI and 90 day interest rates in USA and Australia from 1953 through 1971. He finds that the Fisher hypothesis holds in US and Australia. He also conducts Granger causality test to find that CPI influence nominal interest rates. Atkins and Chan (2004) find support for the hypothesis that the nominal interest rate and inflation in Canada are stationary around a deterministic trend with two breaks. The results indicate that there are three regimes in the interest rate inflation relation. Berument(1999) assesses the effect of expected inflation and inflation risk on interest rates within the Fisher

[1] Statistics are cited from Semiannual OTC derivatives statistics at end-December 2006. At the end of December 2006, the notional outstanding volume of transactions of yen interest rate derivatives was 37,954 billions of US dollars. For details, see BIS (2007).

[2] Cooray (2003) provides the survey for the Fisher hypothesis.

hypothesis framework. With the UK quarterly data from 1958:4 to 1994:4, he concludes that both the expected inflation and the conditional variability of inflation positively affect the UK three-month treasury bill rate.

Berument et al (2007) tests the validity of the Fisher hypothesis for the G7 countries and 45 developing economies. The Fisher relation holds in all G7 countries, but in only 23 developing countries. There is a positive and statistically significant relationship between interest rates, and inflation uncertainty for six of the G7 and 18 of the developing countries and this relationship is negative for seven developing countries. As for Japan they conclude that the Fisher hypothesis holds for the period of 1957 through 2004. Due to the availability of data in Japan, they use lending rate instead of treasury bill rate.

Berument and Jelassi (2002) find supporting evidence for the Fisher hypothesis in 16 out of 26 countries. It is also likely that the Fisher hypothesis holds more for the developed countries than the developing ones in the sample. The Fisher hypothesis could not be rejected for 9 out of 12 developed countries and for 7 out of 14 developing countries. Bonham (1991) utilizes Engle and Granger cointegration test by using 3 month treasury bills and CPI in US from 1955 through 1986. He concludes that the Fisher hypothesis holds.

Carneiro et al (2002) analyzes monthly data for the period 1980-1997 for three countries that have a recent history of chronic high inflation: Argentina, Brazil and Mexico. A cointegration analysis provides evidence of a stable long-run equilibrium relationship between nominal interest rates and the inflation rate for the cases of Argentina and Brazil only. Granville and Mallick (2004) use annual data over a long time horizon from 1900 to 2000 for the UK. Thy conclude that the cointegrating relationship between the two variables suggests a significant long-run equilibrium with a positive coefficient of more than one during the stated period.

Inder and Silvapulle (1993) use Engle and Granger cointegration test between bankers acceptance rates and CPI in Australia. They conclude that the Fisher hypothesis doesn't hold. MacDonald and Murphy (1989) conduct Engle and Granger cointegration test by using 3 month treasury bills and CPI in US and Canada, UK, Belgium from 1955 through 1973. They find that the Fisher hypothesis is effective in 4 countries. Then they divide the whole sample into two. The first sub sample is from 1955 through 1973 (second quarter) - fixed exchange regime. The second sub sample is from 1973 (third quarter) through 1986. Their conclusions are that the Fisher hypothesis holds in US and Canada in the first sub sample, but the validity of the hypothesis can't be found in 4 countries in the second sub sample.

Mishkin (1992) resolves the puzzle of why a strong Fisher effect occurs only during certain periods but not for others. Empirical evidence finds no support for a short-run Fisher effect in which a change in expected inflation is associated with a change in interest rates, but supports the existence of a long-run Fisher effect in which inflation and interest rates have a common stochastic trend when they exhibit trends. These results indicate that a strong Fisher effect will only appear in samples where inflation and interest rates have trends.

Moosa and Kwiecien (2002) examine the viability of using short-term interest rates to forecast inflation implied by the Fisher hypothesis. They demonstrate that, using quarterly data for OECD countries, that by allowing for seasonality in the inflation rate it is possible to obtain a model with a high degree of forecasting accuracy and efficiency. Payne and Ewing (1997) examine the Fisher hypothesis for nine less developed countries. They conclude that the Fisher hypothesis holds only in Malaysia, Pakistan and Sri Lanka.

Yu (1997) examines the nominal interest rate with the IS-LM model incorporating the Fisher hypothesis. Eight different interest rates are considered for different sample periods ending in 1993. He concludes that the Fisher hypothesis only holds for the federal funds rate or the AAA bond rate. Wallace and Warner (1993) test the Fisher hypothesis by using 3 month treasury bills, 10 year treasury bonds and CPI. They conduct Johansen cointegration test. They conclude that the Fisher hypothesis holds.

Woodward (1992) tests the fisher hypothesis by using the inflation indexed securities to obtain the direct data of inflation expectations and real interest rates. He concludes that the coefficients on the expected rate of inflation are approximately equal to one. Wong and Wu (2003) find more support for the Fisher hypothesis when the model is estimated by an instrumental variables estimation method using long-horizon data than by OLS using short horizon data.

Kamae (1999) conducts empirical analysis using Japanese Government Bond (4 Year, 6 Year, 8 Year). He estimates expected inflation from CPI (Consumer Price Index) by using Kalman Filter. The period is from 1977 through 1995. Ito (2003) concludes that the Fisher hypothesis holds in the term structure from 3 year through 10 year in the period from February 1990 through August 1999.

This paper distinguishes other papers in that it analyzes Japanese long term interest rates (interest rate swap market) 2 years, 3 years, 4 years, 5 years, 7 years and 10 years for the period of about 19 years. Especially the sample period including deflationary period when the annualized change of CPI (Consumer Price Index) were negative are included for the analysis of this paper. The annualized change of CPI was negative for about eight years from July 1997 through September 1995.

2. Framework of Analysis

2. 1 *Unit Root Test*

Since the empirical analysis from mid-1980's through mid-1990's show that such data as interest rates, foreign exchange and stocks are non-stationary, it's necessary to check if the data used in this paper contain unit roots. The ADF (Augmented Dickey Fuller) test and the PP (Phillips Perron) test are used. Both the ADF and PP tests define null hypothesis as 'unit roots exist' and alternative hypothesis as 'unit roots don't exist'[3]. Fuller (1976) provides the table for ADF and PP tests.

2. 2 *Cointegration Test*

A cointegration framework is presented to analyze the relationship between nominal interest rate and expected rate of inflation. Non-stationary time series wander widely with their own short-run dynamics, but a linear combination of the series can sometimes be stationary so that they show co-movement with long-run dynamics. This is called as cointegration by Engle and Granger (1987). In the test of the Fisher hypothesis by cointegration, the equation (1) is estimated by OLS to find if residual contains unit root.

$$i_t = \alpha + \beta E_t(\pi_{t+j}) + u_t \tag{1}$$

i_t = nominal interest rates
$E_t(\pi_{t+j})$ = expected rate of inflation

When series i_t and $E_t(\pi_{t+j})$ are both non-stationary $I(1)$, they are called to be in a relationship of cointegration if their linear combination is stationary $I(0)$. The cointegration relationship between i_t and $E_t(\pi_{t+j})$ implies that nominal interest rates and expected rate of inflation move together in the long run equilibrium.

In addition to testing if nominal interest rates and expected inflation rates are in a relationship of cointegration, cointegration vector (1,-1), β in the equation (1), is checked with the method of dynamic OLS by Stock and Watson (1993). The equation (2) is used to test if $\beta = 1$ can be rejected. $\Delta E_{t-i}(\pi_{t+j-i})$ is lead and lag variables of expected inflation rates[4]. If $\beta = 1$ can't be

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[3] See Dickey and Fuller (1979) and Dickey and Fuller (1981). See Phillips and Perron (1988).

[4] As for the number of lead and lag terms, 12 is used. In the case of 6 and 9, the results are the same. Hirayama and Kasuya (1996) provides empirical analysis using Rats procedure SWDYNAMIC.PRG.

rejected, nominal interest rates change with an equivalent degree of expected inflation rates.

$$i_t = \alpha + \beta E_t(\pi_{t+j}) + \sum_{i=-p}^{p} b_i \Delta E_{t-i}(\pi_{t+j-i}) + u_t \qquad (2)$$

3. Data

3. 1 Expected Rate of Inflation [5]

Some form of distributed lag on past inflation is used as a proxy for inflationary expectations in the analysis of Fisher hypothesis. This approach is found in Gibson (1970). With the theory of rational expectations pioneered by Muth (1961), and the theory of efficient markets advanced by Fama (1970), an alternative approach to modeling expectations is developed. This approach is adopted by Fama (1975), Lahiri and Lee (1979), and Levi and Makin (1979). With the incorporation of these theories in the Fisher hypothesis, methods examining the time series properties of the variables are developed. These methods are used by Mishkin (1992), Wallace and Waner (1993), MacDonald and Murphy (1989). Woodward (1992) uses the inflation indexed securities to obtain the direct data of inflation expectations and real interest rates. They start to issue inflation indexed Japanese Government Bond in 2004 in Japan. Thus the accumulation of historical data is not enough for the analysis.

This paper utilizes the method by Wallace and Warner (1993) for a proxy of inflation expectation. They point out that if inflation rates in the past are unit root process, the innovations influence the change of inflation rates in the future. When $E_t(\pi_{t+j})$ defined as expected rates of inflation (they are j periods forward based on the information at the period of t) are random walk, $\pi_{t+1} = \pi_t + \varepsilon_{t+1}$ (ε_{t+1} is an innovation of inflation rates) is established. Here equation (3) is established as for the expected rate of inflation at the time of j.

$$E_t(\pi_{t+j}) = \pi_t \qquad (3)$$

Accordingly π_t defined, as realized rates of inflation at the time of t, indicates the expected rates of inflation in the future. Thus realized rates of inflation are used as inflation expectation after confirming that they are unit root process. Annualized rate of inflation is calculated by using monthly CPI (Consumer Price Index) data (excluding perishables, on a nationwide

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[5] Cooray (2003) provides the survey for the Fisher hypothesis.

statistics). The effects of consumption tax introduction and increase are excluded.[6]

3. 2 Nominal Interest Rates

As for nominal interest rates, Japanese interest rate swap rates of 2 years, 3 years, 4 years, 5 years, 7 years and 10 years as of 3 pm at Tokyo time are used on an end of month basis from October 1987 through June 2006. They are mid rate of offer side and bid side provided by a major bank in Japan.

The data of CPI (annualized rate of inflation) and interest rates of 2 years and 10 years are shown in Figure 1.

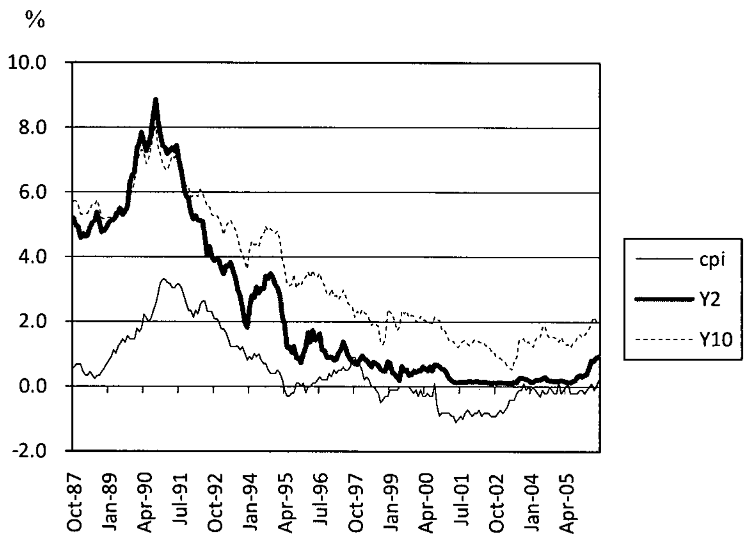

Figure 1 Movement of 3 Series

CPI=Annualized Change of CPI
Y2 = 2 Years Interest Rate Swap Rate
Y10 = 10 Years Interest Rate Swap Rate
3 Series are from October 1987 through June 2006.
The data are on a monthly basis.

[6] As for the CPI 1.3 point which is the increase of March seasonally adjusted number over April in 1989 is subtracted from the data after April 1989. The purpose of doing this is to remove the impacts of consumption tax introduction. In the same way, 1.4 point is subtracted from the data after April 1997 to remove the impacts of the consumption tax increase. CPI data are released by the Ministry of Internal Affairs and Communications. CPI data used for this paper is based on the standard of year 2000.

4. Result

4. 1 Unit Root Test

The results of ADF and PP tests show that all the data have unit root. The results are shown on Table 1. Next, the data with a first difference are confirmed to be stationary by ADF and PP tests. The results are shown on Table 2. From tests of unit root, it's possible to conclude that all the original variables are $I(1)$. Thus it's proper to use non-stationary time series models. The annualized change of CPI can be used as an expected rate of inflation as mentioned before because it's confirmed to be $I(1)$.

Table1. Result of Unit Root Test - Original Data

Variable	Test	Without Trend	With Trend
CPI	ADF	-1.185	-1.899
	PP	-1.007	-1.364
Y2	ADF	-1.448	-1.403
	PP	-1.154	-1.186
Y3	ADF	-1.438	-1.277
	PP	-1.229	-1.404
Y4	ADF	-1.288	-1.441
	PP	-1.229	-1.547
Y5	ADF	-1.280	-1.441
	PP	-1.214	-1.594
Y7	ADF	-1.292	-1.505
	PP	-1.192	-1.636
Y10	ADF	-1.279	-1.555
	PP	-1.180	-1.719

5% critical values are -2.86 (Without Trend), -3.41 (With Trend).
ADF = Augmented Dickey Fuller.
PP = Phillips Perron.

Table2. Result of Unit Root Test - Data with First Difference

Variable	Test	Without Trend	With Trend
CPI	ADF	-4.9367*	-4.835*
	PP	-14.821*	-14.822*
Y2	ADF	-10.678*	-10.614*
	PP	-12.929*	-12.944*
Y3	ADF	-11.229*	-11.103*
	PP	-13.098*	-13.115*
Y4	ADF	-11.520*	-11.360*
	PP	-12.953*	-12.969*
Y5	ADF	-5.630*	-5.642*
	PP	-12.900*	-12.914*
Y7	ADF	-5.638*	-5.625*
	PP	-12.647*	-12.661*
Y10	ADF	-5.782*	-5.772*
	PP	-12.670*	-12.683*

* indicates significance at 5% level.
5% critical values are -2.86 (Without Trend), -3.41 (With Trend).
ADF = Augmented Dickey Fuller.
PP = Phillips Perron.

4. 2 Cointegration Test

Six series of nominal interest rates are not in the relationship of cointegration with expected rates of inflation. The results are shown on Table 3.

Table3. Result of Cointegration Test

Variable	Test Statistics
Y2-CPI	-2.6770
Y3-CPI	-2.8672
Y4-CPI	-2.9539
Y5-CPI	-2.9658
Y7-CPI	-2.8822
Y10-CPI	-2.8517

10% critical value is -3.0462 from MacKinnon (1991).

As for the results of cointegration vector test, $\beta = 1$ can be rejected in all maturities. The results of cointegration vector test show that the expected rates of inflation gave more impacts on nominal interest rates in shorter maturities. The results are shown on Table 4.

Table4. Result of Test on Cointegration Vector

Variable	β	Modified SE	Modified t Value
Y2-CPI	2.2378	0.2679	4.6204*
Y3-CPI	2.2188	0.2329	5.2331*
Y4-CPI	2.1837	0.2198	5.3854*
Y5-CPI	2.1388	0.2208	5.1576*
Y7-CPI	2.0184	0.2265	4.4962*
Y10-CPI	1.8723	0.2121	4.1127*

* indicates significance at 5% level.
$\beta = 1$ can be rejected if modified t value is larger than critical value (1.96).

From the tests of cointegration and cointegration vector, I can conclude that the Fisher hypothesis doesn't hold in all maturities.

5. Concluding Remarks

This paper investigates the validity of the Fisher hypothesis from the Japanese interest rate swap market by using non-stationary time series models. The data used for the analysis are confirmed to be $I(1)$ by unit root tests. From the tests of cointegration and cointegration vector, I can conclude that the Fisher hypothesis isn't valid in the long term interest rates of 2 years, 3 years, 4 years, 5 years, 7 years and 10 years from October 1987 through June 2006. This result isn't surprising since the sample period includes deflationary period when inflation rates were negative and the nominal interest rates decreased to historical low level.

The difference of monetary policy regimes isn't considered in this paper. I would like to divide the whole sample into sub samples depending on the monetary policy regimes so that I will be able to analyze the relationship between monetary policy and the Fisher hypothesis.

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