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On the stationarity of Japanese-yen based purchasing power parity in the presence of the structural breaks

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Abstract

In this paper we perform the stationarity test on the Japanese-yen based real exchange rate of major trade partners of Japan, and we investigate the existences of relative PPPs with these countries and areas. The empirical analyses support that relative PPPs with the United States, Germany (with marks and euro), Korea and Taiwan are upheld when we consider the constant, linear trend and structural breaks. However, relative PPP is not upheld with China (Mainland).

1. Introduction

In this paper we perform an empirical analysis of Purchasing Power Parity (hereafter PPP). We focus on the Japanese yen-based PPPs with the United States, Germany, China (Mainland), Taiwan and Korea; they are major trade partners of Japan (See Table I).

PPP is a standard assumption of modern theory in international macroeconomics. It implies that the prices of the consumption goods' basket based on the same currency are equal in all countries. The *absolute* PPP is explained as follows:

$$\ln(\pi_t) = \ln\left(\frac{p_t^d}{p_t^f}\right). \tag{1}$$

- π_t : the nominal exchange rate of domestic currency per foreign currency

- p_t^d : domestic price level

- p_t^f : foreign price level

Then, taking the difference between the left and right sides of Eq. (1), we obtain

$$s_t = \ln(\pi_t) - \ln\left(\frac{p_t^d}{p_t^f}\right). \tag{2}$$

The variable s_t is the log of the real exchange rate. And if and only if the real exchange rate obeys the stationary process, absolute PPP would be upheld. Trading has an important role in Japanese economy, and therefore the conditions of the exchange rate between Japan and the major trading partners are a serious issue that must be investigated. Thus, it is important to perform empirical analyses on relative PPP by verifying the stationarity of the real exchange rate.

However, *absolute* PPP is seldom held with macroeconomic data. And it is general to analyze *relative* PPP, which is written as follows:

$$\Delta \ln(\pi_t) = \Delta \ln\left(\frac{p_t^d}{p_t^f}\right). \tag{3}$$

Only the growth rates of both variables are the same in this specification, and we can rewrite s_t as

$$s_t = const. + \ln(\pi_t) - \ln\left(\frac{p_t^d}{p_t^f}\right). \tag{4}$$

Thus, we can verify the existence of *relative* PPP by performing the unit root test or stationarity test considering the constant term.

In this study we perform the unit root test following the approach of Kwiatkowski,

Phillips, Schmidt, and Shin (1992) (hereafter KPSS) and Lee, Huang and Shin (1997). KPSS (1992) presents the unit roots test with null of stationary and Lee et al. (1997) develops the stationarity test considering a structural break. And in this study, we consider two cases; one with constant and with constant and linear trend.

Azali et al. (2001) performs the empirical analyses on Japanese yen-based PPPs of Asian countries, however, this study focuses on the period of pre-financial crisis in Asia and does not include structural breaks in the models or the equations themselves. Nusair (2004) employs the Perron(1989)'s unit root test considering the one given break point for the Japanese yen-based real exchange rate of Asian developing countries, and accepts the null of the unit root except for Indonesia. Here, we attempt to re-examine these tests and perform the stationarity test on Japanese yen-based real exchange rates considering structural breaks following the other methods developed in Lee et al. (1997).

In Section 2, we perform the stationarity tests. In Section 3, we present the concluding remarks.

2. Unit root test with null of stationary

Here, we perform the stationarity tests of s_t derived in Eq. (4). As mentioned before, we focus on the Japanese yen-based exchange rate of the United States dollar, German mark (by 1998), euro (after 1999), Chinese renminbi (hereafter RMB), Taiwan's new Taiwan dollar (hereafter NTD) and Korean won. Germany adopted the Euro in 1999. The details of data are shown in the Appendix.

In the unit root test, the null hypothesis implies non-stationary (for example, ADF test). However, many studies show that these kinds of unit root have problems of power: under-rejection of the null of non-stationary. Then, we perform the unit roots test with the null hypothesis of *stationary*. In KPSS test, we assume s_t obeys the following equation:

$$s_t = r_t + \varepsilon_t \qquad (5)$$
$$r_t = r_{t-1} + u_t \qquad (6)$$

Here, u_t follows $iid(0, \sigma_u^2)$ process and ε_t is assumed to be stationary. Null and alternative hypothesis are

$$H_0 : \sigma_u^2 = 0, H_A : \sigma_u^2 > 0$$

The null hypothesis of KPSS test implies that random walk component r_t is constant and that s_t stationary. Thus, the corresponding models are

(C-model) $s_t = \alpha + \varepsilon_t$ \qquad (7)
(CT model) $s_t = \alpha + \gamma t + \varepsilon_t$ \quad (*t*: trend) \qquad (8)

The test statistics LM is written as

$$LM = \frac{1}{T^2} \sum_{t=1}^{T} \frac{S_t^2}{s^2(l)}$$ (9)

.

Here, $S_t^2 = \sum_{\tau=1}^{t} e_\tau$ where e denotes residual in Eq. (7) and (8). And $s^2(l)$ is the long-run variance that considers the l-th length of lags.

And Lee et al. (1997) develops the stationarity test considering a structural break with given point. We consider the following corresponding models in place of Eq. (7) and (8) :

(Model 1) $s_t = \alpha + \delta D_t + \varepsilon_t$ (10)

(Model 2) $s_t = \alpha + \gamma t + \delta_1 D_t + \delta_2 DT_t + \varepsilon_t$ (11)

where $D_t = 1$ for $t = \tau$ and $DT_t = t - (\tau - 1)$ for $t \geq \tau$. Lee et al. (1997) shows that the test statistics under the null has the same asymptotic distribution as KPSS.

We perform the KPSS (1992)'s stationarity tests and Lee et al. (1997)'s test, and obtained the following results.

Following the results of the KPSS (1992) test, the Japanese yen-based real exchange rate of the German mark (January 1991 - December 1998) is stationary considering the constant. And it is also shown that the real exchange rate of the euro (January 1999 - December 2007) is stationary considering the constant and linear trend. Thus, it is shown that Japanese yen-based PPP with Germany is upheld. The details are shown in Table Ⅱ.

Then, we show the results of Lee et al. (1997)'s test: KPSS test in the presence of *given* structural breaks. We set the break point in each currency following Fig. 1, which presents the plots of real exchange rates. Following these figures, we assume that the real exchange rates of NTD and the US dollar have had breaks in April 1995. In April 1995, the value of the Japanese yen with respect to the US dollar reached the highest point according to the data on the market rate (See Fig.1). The German mark is assumed to have shifted in July 1993. The Chinese RMB is assumed to have shifted in July 2005. In July 2005, the RMB was revalued. The Korean won is assumed to have had a structural shift in December 1997, when the Asian financial crisis occurred. The euro is assumed to have had a break in October 2000.

The results of tests with Model 1 (with constant) show that nothing is stationary. However, the results of tests with Model 2 (with constant and linear trend) show that almost all real exchange rates except for the Chinese RMB are stationary. The details of the results are shown in Table Ⅲ.

In these empirical analyses, we assume $l = 6$, where l denotes the length of lags in the long-run variance developed by Newey and West (1987).

3. Concluding remarks

As shown by empirical results presented in the previous section, we examined the stationarity of the Japanese yen-based real exchange rate and investigated the *relative* PPPs.

The results show that the Japanese yen-based PPP with Germany is upheld without structural breaks. The results also show that Japanese yen-based real exchange rates of the US dollar, mark, euro (for Germany), Korean won and Taiwan NTD are stationary when we consider the constant, linear trend and structural breaks. Thus, *relative* PPPs are upheld with major trading partners of Japan except for China. The results for Korea and Taiwan are similar to ones obtained in Azali (2001); it supports the Japanese yen-based PPP with Korea and Taiwan following the cointegration analyses before Asian financial crisis. And the empirical results obtained in this study are different from that of Nusair (2004); it shows that the Japanese yen-based PPP with Korea was not held following Perron (1989)'s test.

However, relative PPP is not upheld with the Chinese RMB in any cases. The causes of these phenomena might be the strong controls of governments. In China, the exchange rate of the RMB with the US dollar is fixed in order to promote and protect the exports industries in China. However, the price level in China has been increasing with the rapid economic growth over the last decade, and there exists a gap between the price level and the nominal exchange rate.

As a future work, we will determine whether the constraint for the relative PPP is really valid. In order to be held the PPP, the coefficients on foreign price should be -1 and that of domestic price should be 1 in Eq. (2). Thus, we will perform cointegration analysis and investigate the validity of this constraint.

Studies on the relationship between PPPs are also important. Choudhry (2005) shows that the real exchange rates of Asian currencies (Korean won, Thai baht, Malaysia ringgit, Indonesia rupiah and Philippine peso) based on the Japanese yen were cointegrated after the Asian currency crisis. We will perform the cointegration analysis considering the structural break(s) in the model in a future work.

Appendix: Data description

The frequency of data is monthly. We employ CPI as the price level and exchange rate at the end of the period as π_t [1]. Only the data of Taiwan is the period average.

The CPI of Germany after 1999 is the harmonized CPI, which can be utilized from 1995. The sample periods are January 1990-December 2007 for the United States (US dollar) and Korea (Korean won). The sample period of China (RMB) is January 1994-December 2007, because the dual exchange rate system was unified in 1994. And we utilize the data of Taiwan (NTD) from January 1990 to December 2006, Germany (with mark) from January 1991 to December 1998 and Germany (with euro) from January 1999 to December 2007[2] [3].

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[1] We take the data except for that of Taiwan from International Financial Statistics (IFS) purchased by Okayama Shoka University Library. However, as the price level in China (mainland), only the growth rate of the CPI is available. In this study, we calculate the price index by having the price level at 1990:M1 be 100.
[2] We take the data of Taiwan from the web site of the Central Bank of Republic of China (exchange rate) and from the Statistical Bureau of Republic of China (CPI).
[3] Germany was unified in 1990, and the dataset of *unified* Germany are also available from January 1991.

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The Euro was established in February 1999 as the money for settlements of interbank trades.

Table Ⅰ: Share of Exports/Import of each Country and Area

Note: The table shows countries and areas in the list of the top 10 trading partners (both imports and exports) of Japan.

Source: Japan External Trade Organization (JETRO)

Exports from Japan(Share)						Imports to Japan(Share)					
year	United States	China	Korea	Germany	Taiwan	year	United States	China	Korea	Germany	Taiwan
1990	31.5	2.1	6.1	6.2	5.4	1990	22.3	5.1	5	4.9	3.6
1991	29.1	2.7	6.4	6.6	5.8	1991	22.5	6.0	5.2	4.5	4
1992	28.2	3.5	5.2	6	6.2	1992	22.4	7.3	5	4.6	4.1
1993	29.2	4.8	5.3	5	6.1	1993	23	8.5	4.9	4.1	4
1994	29.7	4.7	6.2	4.5	6.2	1994	22.8	10.0	4.9	4.1	3.9
1995	27.3	5	7.1	4.6	6.5	1995	22.4	10.7	5.1	4.1	4.3
1996	27.2	5.3	7.1	4.4	6.3	1996	22.7	11.6	4.6	4.1	4.3
1997	27.8	5.2	6.2	4.3	6.5	1997	22.3	12.4	4.3	3.7	3.7
1998	30.5	5.2	4	4.9	6.6	1998	23.9	13.2	4.3	3.8	3.6
1999	30.7	5.6	5.5	4.5	6.9	1999	21.6	13.8	5.1	3.7	4.1
2000	29.7	6.3	6.4	4.2	7.5	2000	19	14.5	5.4	3.4	4.7
2001	30	7.7	6.3	3.9	6	2001	18.1	16.5	4.9	3.6	4.1
2002	25.5	9.6	6.9	3.4	6.3	2002	17.1	17.1	4.6	3.7	4
2003	24.6	12.2	7.4	3.5	6.6	2003	15.4	15.4	4.7	3.7	3.7
2004	22.5	13.1	7.8	3.4	7.4	2004	13.7	13.7	4.8	3.8	3.7
2005	22.6	13.4	7.8	3.1	7.3	2005	12.4	12.4	4.7	3.5	3.5
2006	22.5	14.3	7.8	3.2	6.8	2006	11.8	11.8	4.7	3.2	3.5
2007	20.1	15.3	7.6	3.2	6.3	2007	11.4	11.4	4.4	3.1	3.2
					(%)						(%)

Table Ⅱ: KPSS test

Note: ＊＊ denotes the rejection of null at 5 % level of significant.

＊＊＊ denotes the rejection of null at 1 % level of significant.

The critical values are 0.463(5%) and 0.739 (1%) with constant.

The critical values are 0.146(5%) and 0.216 (1%) with constant and linear trend.

<With constant >

Country and Area (Currency)	Sample period	Test statistics
China (RMB)	1994M1-2007M12	1.274***
Korea (won)	1990M1-2007M12	0.701**
Germany (marks)	1991M1-1998M12	0.271
Germany (euro)	1999M1-2007M12	1.643***
Taiwan (New Taiwan dollar)	1990M1-2006M12	1.152***
United States (US dollar)	1990M1-2007M12	1.758***

<With constant and linear trend>

Country and Area (Currency)	Sample period	Test statistics
China (RMB)	1994M1-2007M12	0.293***
Korea (won)	1990M1-2007M12	0.586***
Germany (marks)	1991M1-1998M12	0.241***
Germany (euro)	1999M1-2007M12	0.128
Taiwan (New Taiwan dollar)	1990M1-2006M12	0.218***
United States (US dollar)	1990M1-2007M12	0.282***

TableⅢ : Stationarity test with breaks

Note: ＊＊ denotes the rejection of null at 5 % level of significant.

＊＊＊ denotes the rejection of null at 1 % level of significant.

For Model 1, the critical values are 0.463(5%) and 0.739 (1%).

For Model 2, the critical values are 0.146(5%) and 0.216 (1%). (Critical values are same as that of KPSS test.)

<Model 1: with constant>

Country and Area (Currency)	Sample period	Break	Test statistics
China　(RMB)	1994M1-2007M12	2005M7	0.735**
Korea (won)	1990M1-2007M12	1997M12	0.791***
Germany (marks)	1991M1-1998M12	1993M7	0.491**
Germany (euro)	1999M1-2007M12	2000M10	0.953***
Taiwan (New Taiwan dollar)	1990M1-2006M12	1995M4	0.226
United States (US dollar)	1990M1-2007M12	1995M4	0.856***

<Model 2: with constant and linear trend>

Country and Area (Currency)	Sample period	Break	Test statistics
China　(RMB)	1994M1-2007M12	2005M7	0.284***
Korea (won)	1990M1-2007M12	1997M12	0.142
Germany (marks)	1991M1-1998M12	1993M7	0.061
Germany (euro)	1999M1-2007M12	2000M10	0.135
Taiwan (New Taiwan dollar)	1990M1-2006M12	1995M4	0.084
United States (US dollar)	1990M1-2007M12	1995M4	0.090

Fig.1: Japanese yen-based Real Exchange Rate

Source of data: International Financial Statistics (IFS) published by the IMF (except for Taiwan), Central bank of Republic of China and Statistical Bureau of Republic of China (Taiwan)