Labuan Bulletin
OF INTERNATIONAL BUSINESS & FINANCE
Volume 8, 2010 ISSN 1675-7262

TERMS OF TRADE, REAL INTEREST RATE DIFFERENTIAL AND REAL EXCHANGE RATE IN JAPAN: AN EMPIRICAL STUDY

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Abstract

This study examines the real exchange rate determination in Japan. The results of the long-run cointegrating vectors show that an increase in the real oil price will lead to a depreciation of the real exchange rate whilst an increase in productivity differential will lead to an appreciation of the real exchange rate. The results of the error correction models show that the real oil price, productivity differential, and the real interest rate differential are important in the real exchange rate determination. The results of the generalized forecast error variance decompositions show that productivity differential is relatively more important than the real oil price in the real exchange rate determination. Generally, the real oil price, productivity differential, and the real interest rate differential are important in the real exchange rate determination in Japan.

JEL Classification: F31; F37; F10
Keywords: Real Exchange Rate; Real Oil Price; Productivity Differential; Real Interest Rate Differential; Cointegration; Variance Decomposition

1. Introduction

The world oil price fluctuated in the 2000s. In 2000, the mean of the weekly world oil price was the United States (US) dollar 27.07 per barrel. The mean of the weekly world oil price increased to the US dollar 75.74 per barrel in July 2010. In the period 2000-July 2010, the standard deviation of the mean of the weekly world oil price was 24.60 and kurtosis and skewness of the mean of the weekly world oil price

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were 2.00 and 0.43, respectively (Table 1). Thus the distribution of the weekly world oil price was not normal and skewed. Askari and Krichene (2008) find that oil price was characterised by high volatility, high intensity jumps, and strong upward drift for the period 2002-2006. These characteristics were consistent with the changes in the oil market and the world economy, that is, oil supply was rigid and uncertain and oil demand was high. The world oil price increased as a result of excess demand in the world oil market. Moreover, the world oil price was expected to be volatile and jumpy with a higher probability to increase above the expected mean (Askari and Krichene, 2008: 2135). The real oil price could influence the real exchange rate (Bergvall, 2004; Chen and Chen, 2007; Huang and Guo, 2007; Narayan, Narayan, and Prasad, 2008; Lizardo and Mollick, 2010).

Economic growth in Japan was high in the 1960s and 1970s. In the period 1960-1969, the mean of economic growth in Japan was 9 per cent. In the period 1970-1979, the mean of economic growth in Japan was 5.2 per cent. However, economic growth in Japan was low in the 1980s, 1990s, and 2000s. In the period 1980s and 1990s, the means of economic growth in Japan were 3.8 per cent and 1.2 per cent, respectively. In 2000, economic growth in Japan was 2.8 per cent. In 2008, economic growth in Japan was 3.7 per cent (Table 2). According to the Balassa (1964) and Samuelson (1964) (BS) hypothesis, an increase in productivity in the tradable goods sector will raise wages in the entire economy and producers of non-tradable goods will not able to meet these higher wages unless there is a rise in the relative price of non-tradable goods. The BS hypothesis is an empirically useful framework for investigating the long-run behaviour of the real exchange rate (Chinn, 2000; Miyakoshi, 2003; Wang and Dunne, 2003; Bergvall, 2004; Alexius, 2005; Choudhri and Khan, 2005; Candelon *et al.*, 2007; Guo, 2010). Economic growth could affect the real exchange rate.

This study examines the real exchange rate determination in Japan using quarterly data for the period 1960:I-2008:III. More specifically, this study examines the impact of the real oil price and productivity differential on the real exchange rate determination. The real oil price is argued to be important in the real exchange rate determination (Bergvall, 2004; Chen and Chen, 2007; Lizardo and Mollick, 2010). The world oil price is volatile (Askari and Krichene, 2008). Thus the real exchange rate would be volatile as well. Japan is a net-oil importing country. The impact of the real oil price on the real exchange rate could be different between the net-oil importing country and the net-oil exporting country (Bergvall, 2004). The empirical evidence of the impact of the real oil price on the real exchange rate in Japan is limited. Japan achieved slow economic growth for the past decades. Economic growth could influence the real exchange rate. Japan adopts an independently floating exchange rate regime, which exchange rate is market determined. Official foreign exchange market intervention is aimed to moderate the rate of change and not to set a level for it (Fischer, 2008). For an independently floating exchange rate regime, the real exchange rate is strongly influenced by the external shocks such as the real oil price shock. Nonetheless, Japan is relatively a closed economy. In the period 1960-1999, the mean of trade openness of Japan, where trade openness is measured by the ratio of trade of goods and services to GDP multiplied by 100, was about 20 per cent. In 2000, trade openness of Japan was 20.60 per cent. In 2008, trade openness was 34.73 per cent. In the period 1960-2008, trade openness was not more than 40 per cent (Table 2). For a closed economy, the impact of the external shocks such as the real oil price shock on the real exchange rate could be limited. This study provides some evidence of the impact of the real oil price, productivity differential, and the real interest rate differential on the real exchange rate in an independently floating exchange rate regime and a relatively closed developed economy. This study uses two measures of the real interest rate differential to examine their impact on the real exchange rate.

Table 1
The Mean of the Weekly World Oil Price (US Dollar), 2000-July, 2010

Year	US Dollar
2000	27.07
2001	22.73
2002	23.47
2003	27.11
2004	34.62
2005	49.87
2006	60.32
2007	69.19
2008	95.62
2009	60.07
July, 2010	75.74

	2000 - July, 2010
Mean	49.62
Median	49.87
Standard Deviation	24.60
Kurtosis	2.00
Skewness	0.43
Minimum	22.73
Maximum	95.62

Source: U.S. Energy Information Administration.

Table 2
Economic Growth and Trade Openness in Japan (%), 1960-2008

Year	Growth	Openness
1960-1969	9.0	19.45
1970-1979	5.2	22.88
1980-1989	3.8	23.39
1990-1999	1.2	18.39
2000	2.8	20.60
2001	0.2	20.52
2002	0.3	21.50
2003	1.5	22.38
2004	2.7	24.78
2005	1.9	27.24
2006	2.0	30.88
2007	4.4	33.57
2008	3.7	34.73

Source: IFS, IMF.
Notes: Growth denotes economic growth. Openness denotes trade openness.

The rest of this study is structured as follows. Section 2 gives a literature review of the real exchange rate determination. Section 3 provides a theoretical framework for the real exchange rate determination. Section 4 explains the data and methodology used in this study. Section 5 presents empirical results and discussions. The last section provides some concluding remarks.

2. A Literature Review

The real oil price could influence the real exchange rate. Chen and Chen (2007) analyse the impact of the real oil price on the real exchange rate in the G7 countries namely Canada, France, Germany, Italy, Japan, the United Kingdom, and the US using a monthly panel data for the period 1972:1-2005:10. The results of the Johansen's cointegration method (Johansen, 1988) exhibit that there is a link between the real oil price and the real exchange rate. Moreover, the panel predictive regression suggests that the real oil price has significant forecasting power. The out-of-sample prediction performances demonstrate greater predictability over longer horizons. Furthermore, the results exhibit the real interest rate differential and productivity differential to have important impact on the real exchange rate.

Huang and Guo (2007) investigate the impact of oil price and other three types of underlying macroeconomic namely supply, demand, and monetary shocks on the real exchange rate in China using a four-variable structural vector autoregression (SVAR) model. The study uses monthly data for the period 1990:1-2005:10. On the whole, the results reveal that the real shocks rather than the nominal shock are found to be dominant in the variations of the real exchange rate. An increase in the real oil price will lead to an appreciation of the real exchange rate in China. This is because of China less dependence on imported oil than its trading partners included in the basket peg regime of currency of China and less synchronisation of movements of the real oil price in China with the world markets as a result of the energy regulation by the government of China.

Narayan, Narayan, and Prasad (2008) examine the relationship between oil price and the Fiji-US dollar exchange rate using daily data for the period 2000-2006. The generalized autoregressive conditional heteroskedasticity (GARCH) and exponential GARCH (EGARCH) models are used to estimate the impact of oil price on the nominal exchange rate. The results demonstrate that a rise in oil price will lead to an appreciation of the Fiji-US dollar exchange rate. More specifically, a 10 per cent increase in oil price will lead to a 0.2 per cent appreciation of the Fiji-US dollar exchange rate. Lizardo and Mollick (2010) find that oil prices significantly explain movements in the value of the US dollar against major currencies using monthly data for the period from the 1970s to 2008. An increase in the real oil price will lead to a depreciation of the US dollar against the currencies of the net-oil exporting countries namely Canada, Mexico, and Russia. The currency of the net-oil importing country namely Japan, depreciate against the US dollar when the real oil price increases. The US dollar against the currencies of neither the net-oil exporting countries nor the net-oil importing countries namely the United Kingdom and the European Union tend to decrease.

Bergvall (2004) examines the impact of the real oil price, relative labour productivity, which is expressed by differential in Gross Domestic Product (GDP) per employee, and trade balance on the real effective exchange rate and finds that these variables are cointegrated. Generally, the real oil price is found to have a significant impact on the real effective exchange rate. An increase in relative labour productivity or trade balance will lead to an increase in the real effective exchange rate. The results of variance decompositions show that demand factor accounts for most of the long-run variance in the real effective exchange rates for Finland and Sweden whilst the real oil prices are found to be the most important determinant of the long-run movement in the real effective exchange rates for Norway and Denmark. The study finds the importance of the BS hypothesis. Guo (2010) assesses the extent to which both the official and black market exchange rates for the Chinese economy exhibit compatibility with the BS hypothesis using time series and panel data for the period 1985-2006. The results show that, amongst others, the black market exchange rate appears more consistent with the predictions of the BS hypothesis than the official exchange rate. Choudhri and Khan (2005) find that, amongst others, the BS hypothesis is useful to predict the long-run behaviour of the real exchange rate. Chinn (2000), Miyakoshi (2003), Wang and Dunne (2003), Bergvall (2004), Alexius (2005), and Candelon *et al.* (2007), amongst others, report the importance of productivity differential in the real exchange rate determination.

Kim (2007) examines the link between the real exchange rates and the real interest rate differentials for tradable goods and non-tradable goods in a dynamic seemingly unrelated cointegrating regression. The study uses quarterly and panel data for the period 1974:I- 2003:IV for Canada, Japan, Italy, the United Kingdom, and the US. The results demonstrate that the link between the real exchange rate and the real interest rate differential is more favourable for tradable goods than for general and non-tradable goods. Hoffmann and MacDonald (2009) analyse the relationship between the real exchange rates and the real interest rate differentials for six US dollar bilateral exchange rates against Japan, Germany, France, Italy, the United Kingdom, and Canada, respectively. The study uses quarterly data for the period 1978:I-2007:III. The results reveal that the real interest rate differentials constitute a good proxy for the temporary component in the real exchange rates. Gruen and Wilkinson (1994), Bagchi, Chortareas, and Miller (2004), and Byrne and Nagayasu (2010), amongst others, find the real interest rate differential has a significant impact on the real exchange rate.

3. A Theoretical Framework

A theoretical framework of the real exchange rate determination can be demonstrated using the purchasing power parity and the uncovered interest rate parity. The real exchange rate is defined as follows:

$$q_t \equiv e_t + p_t^* - p_t \tag{1}$$

where q_t is the logarithm of the real exchange rate, e_t is the logarithm of the nominal exchange rate, which is defined as the unit of domestic currency per unit of foreign currency, p_t^* is the logarithm of the foreign price level, and p_t is the logarithm of the domestic price level.

The uncovered interest rate parity is defined as follows:

$$E_t e_{t+k} - e_t = i_t - i_t^* \tag{2}$$

where E_t is the expectation operator, e_{t+k} is the logarithm of the nominal exchange rate at period t for k period ahead, i_t is the nominal domestic interest rate, and i_t^* is the nominal foreign interest rate. Thus the real uncovered interest rate parity can be defined as follows:

$$E_t q_{t+k} - q_t = r_t - r_t^* \tag{3}$$

where r_t is the real domestic interest rate and r_t^* is the real foreign interest rate.

When the real shocks do not affect the expected long-run equilibrium value of the real exchange rate or when there is no real shock, then

$$E_t q_{t+k} = \bar{q}_t \tag{4}$$

where $\bar{q}_t$ is the logarithm of the long-run equilibrium real exchange rate.

Solving equations (3) and (4) yields:

$$q_t = r_t - r_t^* + \bar{q}_t \tag{5}$$

When the foreign exchange market is in equilibrium or when the nominal exchange rate follows a random walk in the face of the real shocks, $\bar{q}_t$ can be written as follows:

$$\bar{q}_t = \bar{e}_t + p_t^* - p_t \tag{6}$$

where $\bar{e}_t$ is the logarithm of the long-run equilibrium nominal exchange rate (Bagchi, Chortareas, and Miller, 2004).

The domestic and foreign price levels can be defined respectively as follows:

$$p_t = \alpha p_t^N + (1-\alpha) p_t^T \tag{7}$$

$$p_t^* = \alpha^* p_t^{N*} + (1-\alpha^*) p_t^{T*} \tag{8}$$

where α is the share of the expenditure for non-tradable goods in the domestic country, α^* is the share of the expenditure for non-tradable goods in the foreign country, p_t^N is the logarithm of the price of non-tradable goods in the domestic country, p_t^T is the logarithm of the price of tradable goods in the domestic country, p_t^{N*} is the logarithm of the price of non-tradable goods in the foreign country, and p_t^{T*} is the logarithm of the price of tradable goods in the foreign country (Engel, 1993, 1999).

Substituting equations (7) and (8) into equation (6) and re-arranged yields:

$$\bar{q}_t = \bar{e}_t + (p_t^{T*} - p_t^T) - [\alpha(p_t^N - p_t^T) - \alpha^*(p_t^{N*} - p_t^{T*})] \tag{9}$$

Substituting equation (9) into equation (5) yields:

$$q_t = (r_t - r_t^*) + [\bar{e}_t + (p_t^{T*} - p_t^T)] - [\alpha(p_t^N - p_t^T) - \alpha^*(p_t^{N*} - p_t^{T*})] \tag{10}$$

where the term $(r_t - r_t^*)$ is the real interest rate differential, the term $[\bar{e}_t + (p_t^{T*} - p_t^T)]$ is the inverse terms of trade of the domestic country or the measurement of the real exchange rate for tradable goods, and the term $[\alpha(p_t^N - p_t^T) - \alpha^*(p_t^{N*} - p_t^{T*})]$ is the difference in the relative price of tradable goods to non-tradable goods in the domestic country and the foreign country or this term is equivalent to relative productivity differential which captures the BS hypothesis (Bagchi, Chortareas, and Miller, 2004). It can be demonstrated that the relative price reflect the differential productivity in a two-sector neoclassical framework with perfect capital mobility and interest rate assumed exogenous as follows:[1]

$$p_t^N - p_t^T = \beta a_t^T - a_t^N \tag{11}$$

where β is the ratio of the labour share in tradable goods to the labour share in non-tradable goods and a_t^T is the labour productivity in tradable goods, and a_t^N is the labour productivity in non-tradable goods. The term $p_t^N - p_t^T$ is the growth rate of the relative price of non-tradable goods and the term $\beta a_t^T - a_t^N$ is the growth rate of dual total factor productivity (Egert, 2003, 2004; Choudhri and Khan, 2005; Loko and Tuladhar, 2005). Thus the term $[\alpha(p_t^N - p_t^T) - \alpha^*(p_t^{N*} - p_t^{T*})]$ can be re-written as $[\alpha(\beta a_t^T - a_t^N) - \alpha^*(\beta^* a_t^{T*} - a_t^{N*})]$, where β^* is the ratio of the labour share in tradable goods to the labour share in non-tradable goods in the foreign country and equation (10) can be re-written as follows:

$$q_t = (r_t - r_t^*) + [\bar{e}_t + (p_t^{T*} - p_t^T)] - [\alpha(\beta a_t^T - a_t^N) - \alpha^*(\beta^* a_t^{T*} - a_t^{N*})] \tag{12}$$

where the term $[\alpha(\beta a_t^T - a_t^N) - \alpha^*(\beta^* a_t^{T*} - a_t^{N*})]$ is the difference between dual mean labour productivity at the domestic country and the foreign country or dual productivity differential between the domestic country and the foreign country.

[1]See Egert (2003) for the derivation of equation (11).

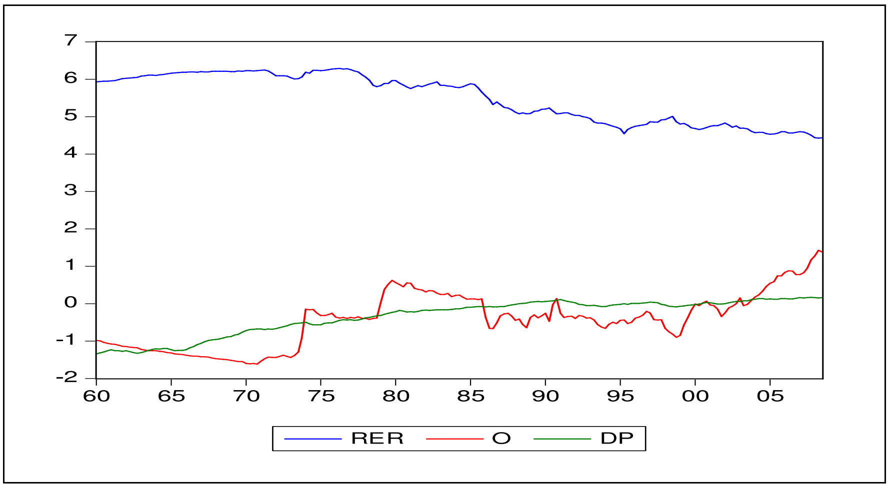
4. Data and Methodology

The nominal exchange rate, Consumer Price Index (CPI, 2000 = 100), the world oil price (2000 = 100), Industrial Production Index (2000 = 100), Manufacturing Employment Index (2000 = 100), and money market rate were obtained from *International Financial Statistics*, the International Monetary Fund (IFS, IMF). The real exchange rate (RER_t) is expressed by $ER_t \times (CPI_{us,t} / CPI_{j,t})$, where ER_t is the Japanese yen against the US dollar and subscripts j and us denote Japan and the US, respectively. Thus an increase in the real exchange rate means a depreciation of the real exchange rate of Japan. The real oil price (O_t) is expressed by the world oil price divided by $CPI_{j,t}$. Productivity differential (DP_t) is expressed by $[(Y_{j,t} / N_{j,t}) - (Y_{us,t} / N_{us,t})]$, where $Y_{i,t}$ ($i = j, us$) is Industrial Production Index and $N_{i,t}$ ($i = j, us$) is Manufacturing Employment Index. The real interest rate differential (DR_t) is expressed by $(r_{j,t} - r_{us,t})$, where $r_{j,t}$ is the real money market rate of Japan and $r_{us,t}$ is the real money market rate of the US. This study uses two measures of the real interest rate differential. First, the real interest rate is expressed by subtracting inflation rate from the nominal interest rate (Chen and Chen, 2007). Inflation rate is measured by the changes of CPI ($DR_{1,t}$). Second, the real interest rate is expressed by subtracting expected inflation rate from the nominal interest rate, which expected inflation rate is expressed by two-year centred moving mean of inflation rate, incorporating both the backward-looking and forward-looking elements ($DR_{2,t}$) (Bagchi, Chortareas, and Miller, 2004: 80).[2] The sample period is 1960:I-2008:III. The choice of sample period is subject to the availability of the data. All the data were seasonal adjusted, except that manufacturing employment is originally seasonal adjusted. All the data were transformed into the natural logarithms before estimation, except interest rate.

Figure 1 displays the plots of the natural logarithms of the real exchange rate, the real oil price, and productivity differential whilst Figure 2 displays the plots of the real interest rate differentials. Generally, these series namely the real exchange rate, the real oil price, and productivity differential move in a same direction. Thus these series tend to be cointegrated. Moreover, there is no strong evidence that there is structural break in these series. The real interest rate differentials are moving closely together.

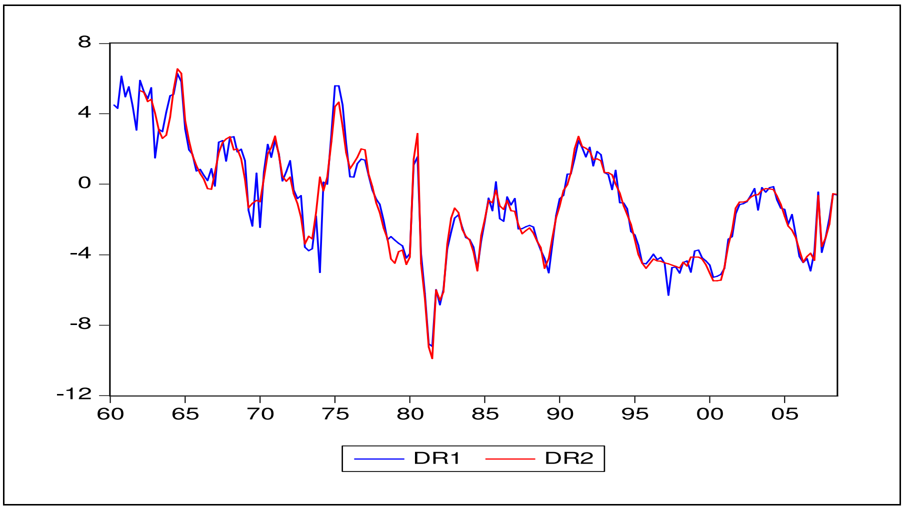
[2]The expected real interest rate differential captures financial market developments especially capital flows (Bagchi, Chortareas, and Miller, 2004: 77).

Figure 1
The Plots of the Natural Logarithms of the Real Exchange Rate, the Real Oil Price, and Productivity Differential



Note: *RER* = log RER_t, *O* = log O_t, and *DP* = log DP_t.

Figure 2
The Plots of the Real Interest Rate Differentials



Note: *DR1* = $DR_{1,t}$ and *DR2* = $DR_{2,t}$.

The model to be estimated is specified as follows:

$$\log RER_t = \beta_{10} + \beta_{11} \log O_t + \beta_{12} \log DP_t + \beta_{13} DR_t + u_{1,t} \qquad (13)$$

where log is the natural logarithm, RER_t is the real exchange rate, O_t is the real oil price, DP_t is productivity differential, DR_t is a measure of the real interest rate differential, and $u_{1,t}$ is a disturbance term. The real oil price is included in the estimation as it is argued to be important in the real exchange rate determination (Bergvall, 2004; Chen and Chen, 2007; Huang and Guo, 2007; Narayan, Narayan, and Prasad, 2008; Lizardo and Mollick, 2010). Moreover, the real oil price is argued to be strongly correlated with terms of trade. Backus and Crucini (2000) use a dynamic general equilibrium model and find that oil price accounted for much of the variation in terms of trade. In the period 1960:I-2008:III, the correlation between the natural logarithm of terms of trade of Japan, which is expressed by $(P_{x,t} / P_{m,t}) \times 100$, where $P_{x,t}$ is the export price and $P_{m,t}$ is the import price and the natural logarithm of the real oil price which is expressed by the world oil price divided by CPI of Japan is -0.95. Thus the two variables are strongly correlated and putting them in the same side of equation in the estimation may lead to the multicollinearity problem. Moreover, the result of the Johansen's cointegration method, which is not reported, shows that the two variables are cointegrated. Furthermore, the Granger causality test shows the uni-directional causality from the natural logarithm of the real oil price to the natural logarithm of terms of trade and not vice verse. Chen and Chen (2007) estimate the real exchange rate in the G7 countries using panel data as a function of the real oil price, productivity differential, and the real interest rate differential.

When the real interest rate differential is a stationary variable, the long-run cointegrating vector shall be estimated without the real interest rate differential as follows:

$$\log RER_t = \beta_{20} + \beta_{21} \log O_t + \beta_{22} \log DP_t + u_{2,t} \quad (14)$$

where $u_{2,t}$ is a disturbance term. Nonetheless, the real interest rate differential shall be entered in the estimation as an exogenous variable. This study uses two measures of the real interest rate differential ($DR_{1,t}$ and $DR_{2,t}$). The vectors with the first and second measures of the real interest rate differential are named Vectors 1 and 2, respectively. The coefficient of the real oil price is expected to be negative for the oil-importing country (Bergvall, 2004). Generally, the coefficients of productivity differential and the real interest rate differential are expected to be negative (Bagchi, Chortareas, and Miller, 2004; Bergvall, 2004; Chen and Chen, 2007).

Engle and Granger (1987) demonstrate that cointegration implies an error correction model. The error correction model for model (14) can be estimated as follows:

$$\Delta \log RER_t = \beta_{30} + \sum_{i=1}^{p} \beta_{31i} \Delta \log O_{t-i} + \sum_{i=1}^{p} \beta_{32i} \Delta \log DP_{t-i} + \sum_{i=1}^{p} \beta_{33i} \Delta \log RER_{t-i} + \beta_{34} DR_t + \beta_{35} EC_{t-1} + u_{3,t} \quad (15)$$

where Δ is the first difference operator, EC_{t-1} is the one period lag of error correction term, and $u_{3,t}$ is a disturbance term. The coefficient of the one period lag of error correction term is expected to have a negative sign. The one period lag of error correction terms generated from the cointegrating vectors are included in the estimation as additional explanatory variables in order to avoid the lost of potentially relevant information.

The Dickey and Fuller (1979) (hereafter DF) and Phillips and Perron (1988) (hereafter PP) unit root test statistics are used to examine the stationary of the data. The Johansen's cointegration method is used to examine the long-run relationship among the variables. The generalized forecast error variance decomposition and generalized impulse response function are used to examine the relationship of the variables. The generalized forecast error variance decomposition identifies the proportion of forecast error variance in one variable caused by the innovations in the other variables. Therefore the relative importance of a set of variables that affect a variance of another variable is identified. The generalized impulse response function traces the dynamic responses of a variable to innovations in the other variables. A key feature of the generalized forecast error variance decomposition and generalized impulse response function (Koop, Pesaran, and Potter, 1996; Pesaran and Shin, 1998) is that they are invariant to the ordering of the variables in the vector autoregressive (VAR). Thus they provide robust results than the orthogonalised method of Sims (1980). Moreover, they allow for meaningful interpretation of the initial impact response of each variable to shocks to any of the other variables because they do not impose orthogonality (Wang and Dunne, 2003).

5. Empirical Results and Discussions

The results of the DF and PP unit root test statistics are reported in Table 3. The lag lengths used to estimate the DF unit root test statistics are based on the Schwarz Bayesian Criterion (SBC). The lag lengths used to compute the PP unit root test statistics are based on the Newey-West automatic bandwidth selection, with the maximum lag length is set to twelve. Generally, the results of the DF and PP unit root test statistics show that all the variables are non-stationary in their levels but become stationary after taking the first difference, except the real interest rate differentials (DR_1 and DR_2).

The results of the cointegration method are reported in Table 4. The results of the λ_{Max} and λ_{Trace} test statistics are computed with unrestricted intercepts and no trends in the VAR. The λ_{Max} and λ_{Trace} test statistics show that there is one cointegrating vector in all the vectors. The results of the normalised cointegrating vectors are reported in Table 5. The lag lengths used to estimate the normalised cointegrating vectors are based on the SBC. The likelihood ratio test statistic for the cointegrating Vector 1 is marginally higher than the likelihood ratio test statistic for the cointegrating Vector 2. The results of the likelihood statistic, which tests that the coefficient of productivity differential is zero, are rejected at the 1 per cent level (Johansen and Juselius, 1990). Productivity differential is important in the real exchange rate determination in the long run. Generally, an increase in the real oil price will lead to a depreciation of the real exchange rate whilst an increase in productivity differential will lead to an appreciation of the real exchange rate.

Table 3
The Dickey and Fuller (1979) (DF) and Phillips and Perron (1988) (PP) Unit Root Test Statistics

	DF - No Trend	PP - No Trend	DF - Trend	PP - Trend
log RER_t	0.1866(1)	0.2437(6)	-2.7202(1)	-2.6501(6)
Δ log RER_t	-9.8102***(0)	-9.9092***(3)	-9.9024***(0)	-9.9986***(3)
log O_t	-0.8577(1)	-0.4105(2)	-2.1096(1)	-1.5826(1)
Δ log O_t	-9.9230***(0)	-9.6395***(7)	-9.9540***(0)	-9.6511***(7)
log DP_t	-2.1969(1)	-2.4971(6)	-1.1519(1)	-1.0676(6)
Δ log DP_t	-8.0309***(0)	-8.0938***(3)	-8.3011***(0)	-8.3057***(2)
$DR_{1,t}$	-3.3673**(0)	-3.2901**(6)	-3.8102**(0)	-3.8667**(5)
Δ $DR_{1,t}$	-14.9304***(0)	-16.0544***(12)	-14.9129***(0)	-16.1156***(12)
$DR_{2,t}$	-3.9127***(1)	-3.3335**(6)	-4.3019***(1)	-3.6005**(5)
Δ $DR_{2,t}$	-10.6473***(0)	-10.4518***(12)	-10.6463***(0)	-10.4727***(12)

Notes: No Trend denotes the DF or PP t-statistic is estimated based on the model including an intercept. Trend denotes the DF or PP t-statistic is estimated based on the model including an intercept and a time trend. Values in parentheses are the lag length used in the estimation of the DF or PP unit root test statistic. The critical values can be obtained from MacKinnon (1996). *** (**) denotes significance at the 1% (5%) level.

Table 4
The Results of the Likelihood Ratio Test Statistics (Johansen, 1988)

Vector 1: λ_{Max} Test Statistic			
H_o:	r=0	r<=1	r<=2
H_a:	r=1	r=2	r=3
1	25.20**	4.09	1.90
2	23.64**	3.97	1.51
c.v. 1	21.12	14.88	8.07
c.v. 2	19.02	12.98	6.50
Vector 2: λ_{Trace} Test Statistic			
H_o:	r=0	r<=1	r<=2
H_a:	r≥1	r≥2	r≥3
1	31.19*	5.99	1.90
2	29.11*	5.47	1.51
c.v. 1	31.54	17.86	8.07
c.v. 2	28.78	15.75	6.5

Notes: The VAR = 2 is used in the estimation. c.v. 1 denotes the 5% critical value. c.v. 2 denotes the 10% critical value. The critical values can be obtained from Pesaran, Shin, and Smith (2000). ** (*) denotes significance at the 5% (10%) level.

Table 5
The Results of the Normalised Cointegrating Vectors

Vector 1	log RER_t = 0.3413 log O_t - 5.8545 log DP_t + 3.6369
	(0.2476) (14.1215***)
	LL = 1029.3
Vector 2	log RER_t = 0.4126 log O_t - 7.0206 log DP_t + 3.4213
	(0.2238) (11.9893***)
	LL = 1001.2

Notes: The VAR = 2 is used in the estimation. Values in parentheses are the likelihood ratio test statistic, which tests the coefficient of explanatory variable is equal to zero. LL is the likelihood ratio test for the cointegrating vector. *** denotes significance at the 1% level.

The results of the error correction models are reported in Table 6. The lag lengths used to estimate the error correction models are based on the SBC. The results of the ordinary least squares (OLS) estimator with the Newey-West adjusted standard errors are presented as the problems of serial correction and heteroscedasticity of disturbance terms when the OLS estimator is used. The adjusted R^2 for Vector 1 is 0.1526 which is marginally higher than the adjusted R^2 for Vector 2, that is, 0.1278. The coefficients of the error correction terms are found to be negative and statistically significant at the 1 per cent level. Figure 3 displays the plots of cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMSQ). There is no evidence of instability of the error correction models. The tests of stability of the regression coefficients (Chow's test) and adequacy of predictions (Chow's second test) provide no evidence of a structural break.[3] Generally, the results show the real oil price, productivity differential, and the real interest rate differential to have a significant short-run impact on the real exchange rate. More specifically, an increase in the real oil price will lead to a depreciation of the real exchange rate whilst an increase in productivity differential or the real interest rate differential will lead to an appreciation of the real exchange rate.

[3]The break point is the time before the outbreak of the Asian financial crisis, that is, at 1997:I.

Table 6
The Results of the Error Correction Models

Vector	1#	2#
constant	-0.0392***	-0.0207
	(3.8041)	(3.1523)
$\Delta \log O_{t-1}$	-0.0097	-0.0077
	(-0.3286)	(-0.2568)
$\Delta \log O_{t-2}$	0.0479*	0.0499**
	(1.9427)	(2.0448)
$\Delta \log DP_{t-1}$	-0.0567	-0.0312
	(-0.4225)	(-0.2223)
$\Delta \log DP_{t-2}$	0.0217	0.0027***
	(0.1320)	(0.0158)
$\Delta \log RER_{t-1}$	0.2661***	0.2728***
	(2.8108)	(2.8544)
$\Delta \log RER_{t-2}$	0.0327	0.0358
	(0.4807)	(0.5222)
DR_t	-0.0036***	-0.0028**
	(-2.8888)	(-2.5982)
EC_{t-1}	-0.0067***	-0.0044***
	(-4.1117)	(-3.7838)

Diagnostic tests:

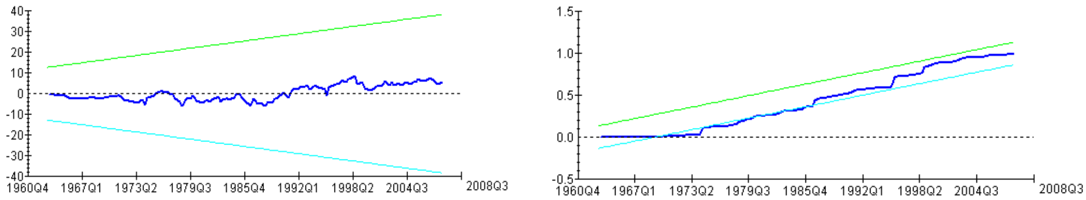
Adj. R^2	0.1526	0.1278
LM(1)	0.11908	9.0380***
LM(2)	5.3142*	2.9655
Reset	0.1000	0.0357
Normal	39.9795***	36.0152
ARCH(1)	8.7096***	9.0847***
ARCH(2)	4.2730**	9.0287***
Hetero	13.2293***	13.1964***
Chow 1	10.9817	9.9668
Chow 2	48.8088	44.9571

Notes: EC_{t-1} is the one period lag of error correction term from the cointegrating vector. Adj. R^2 is the adjusted R^2. LM is the Lagrange multiplier test of disturbance term serial correlation. Reset is the test of functional form. Normal is the test of the normality of disturbance term. ARCH is the Lagrange multiplier test for autoregressive conditional heteroskedasticity (ARCH) in disturbance term (Engle, 1982). Hetero is the test of heteroscedasticity (Koenker, 1981). Chow 1 is the test of stability of the regression coefficients. Chow 2 is the test of adequacy of predictions (Chow's second test). Values in parentheses under the coefficients are the t-statistics whilst values in the parentheses under the diagnostic tests are the lag lengths used in the computing the test statistics. *** (**,*) denotes significance at the 1% (5%, 10%) level.

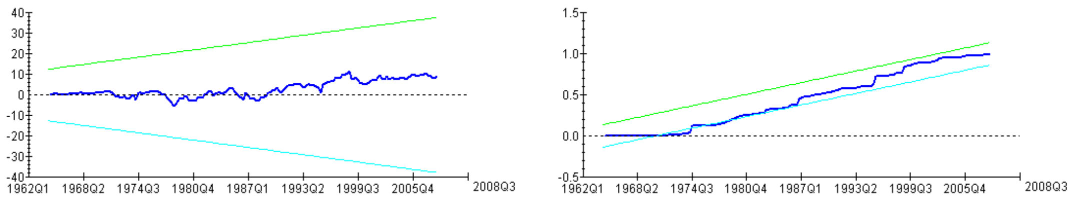
Figure 3
The Plots of Cumulative Sum of Recursive Residuals (CUSUM) and Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ)

CUSUM CUSUMSQ

Vector 1



Vector 2



Note: The straight lines represent critical bounds at the 5% significance level.

The results of the generalized forecast error variance decompositions are reported in Table 7.[4] The choice of the lag used in the estimation of the generalized forecast error variance decomposition is based on the SBC. The results of the generalized forecast error variance decompositions, which are reported, are based on the 0-5, 10, 15, and 20 horizon periods. The results show that productivity differential is relatively important than the real oil price in terms of the contribution to the forecast error variance of the real exchange rate. For Vector 1, productivity differential accounts for about 1 per cent of the forecast error variance of the real exchange rate whilst the real oil price accounts for about 0.5 per cent.

The generalized impulse response function traces the dynamic responses of a variable to innovations in the other variables in the model. The results of the generalized impulse response functions are displayed in Figure 4.[5] The choice of the lag used in the estimation of the generalized impulse response function is based on the SBC. The results of the generalized impulse response functions are plotted over the 20 horizon periods or equivalent to five year periods. For Vector 1, the responses of the real exchange rate to one standard error shock in the real oil price are positive over the 0-14 horizon periods and then die out. The responses of the real exchange rate to one standard error shock in

[4]All variables are in the first differences of the natural logarithms.
[5]All variables are in the first differences of the natural logarithms.

productivity differential are negative over about the 0-6 horizon periods and then die out. Thus a shock in the real oil price will influence the real exchange rate for a longer period than a shock in productivity differential on the real exchange rate.

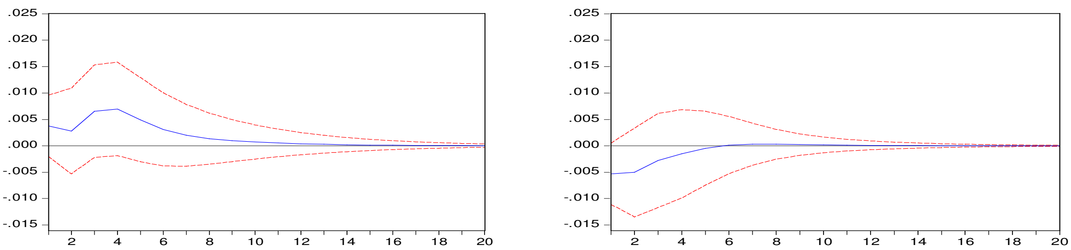
Table 7
The Generalized Forecast Error Variance Decompositions

Horizon	Δ log RER_t	Δ log O_t	Δ log DP_t
	Vector 1		
0	1.0000	0.0047	0.0107
1	0.9988	0.0055	0.0097
2	0.9981	0.0057	0.0098
3	0.9978	0.0058	0.0100
4	0.9977	0.0058	0.0101
5	0.9976	0.0058	0.0101
10	0.9976	0.0058	0.0101
15	0.9976	0.0058	0.0101
20	0.9976	0.0058	0.0101
	Vector 2		
0	1.0000	0.0055	0.0108
1	0.9987	0.0068	0.0097
2	0.9979	0.0071	0.0099
3	0.9976	0.0072	0.0101
4	0.9975	0.0072	0.0101
5	0.9974	0.0072	0.0102
10	0.9974	0.0072	0.0102
15	0.9974	0.0072	0.0102
20	0.9974	0.0072	0.0102

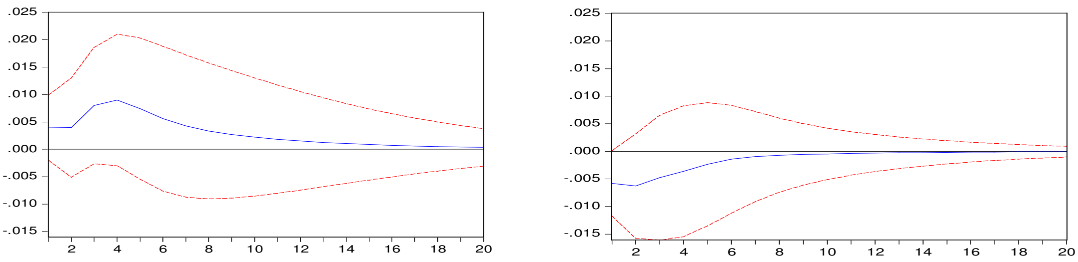
Figure 4
The Plots of the Generalized Impulse Response Functions to one Standard Error Shock in the Equation for the First Difference of the Natural Logarithm of the Real Exchange Rate (Δ log *RER_t*)

Δ log O_t Δ log DP_t

Vector 1



Vector 2



Note: The dashed lines represent ± 2 asymptotic standard errors.

Generally, productivity differential is found to have a significant impact on the real exchange rate in the long run and short run. On the other hand, the real oil price and the real interest rate differential are important to the real exchange rate determination in the short run. The same conclusion is found with different measures of the real interest rate differential. However, the real interest rate differential which is measured by the difference between the real interest rate, that is, subtracting inflation rate from the nominal interest rate is marginally better than the real interest rate, that is, subtracting expected inflation rate from the nominal interest rate in the estimation of the real exchange rate. Choudhri and Khan (2005), amongst others, find that productivity differential is important in the real exchange rate determination in the long run. Bergvall (2004), Alexius (2005), Candelon (2007), and Guo (2010), amongst others, find that the BS hypothesis is useful in the prediction of the real exchange rate. Bergvall (2004), Chen and Chen (2007), Huang and Guo (2007), and Lizardo and Mollick (2010), amongst others, find that the real oil price is important in the real exchange rate determination. Finally, Bagchi, Chortareas, and Miller (2004), Hoffmann and MacDonald (2009), and Byrne and Nagayasu (2010), amongst others, find the real interest rate differential has a significant impact on the real exchange rate. The measures of the real interest rate differential are found to be stationary. Thus there is no long run significant impact of the real interest rate differential on the real exchange rate. One explanation for the stationary of the real interest rate differential is that capital flows adjust simultaneously between Japan and the US.

The external shocks such as the real oil price shock could have a significant impact on the real exchange rate although Japan has a relatively small trade openness ratio. Japan adapts an independently floating exchange rate regime and thus its real exchange rate is volatile to the external shocks. Moreover, Japan is a net-oil importing country and an increase in the world oil price will lead to a depreciation of its real exchange rate. Oil price in the world market is characterised by high volatility and thus the real exchange rate in Japan is expected to be volatile as well. Monetary policy, that is, interest rate policy can be used to influence the real exchange rate especially in the short run as there is no long-run impact of the real exchange rate differential on the real exchange rate. Faster economic growth in Japan relatively to the rest of the world would appreciate its real exchange rate. The slow economic growth in Japan especially in the 2000s perhaps a transition period for its real exchange rate to be depreciated, which will make exports of Japan cheaper and will lead to more exports and a higher economic growth. One policy implication is that the real oil price has a role in the information set when estimating the real exchange rate. Generally, there is a link between commodity and currency world markets. Also, economic growth could affect the real exchange rate.

6. Concluding Remarks

This study has investigated the impact of the real oil price, productivity differential, and the real interest rate differential on the real exchange rate in Japan. Generally, the results of the Johansen's cointegration method show that the real exchange rate, the real oil price, and productivity differential are cointegrated. Generally, an increase in the real oil price will lead to a depreciation of the real exchange rate. An increase in productivity differential will lead to an appreciation of the real exchange rate. The results of the error correction models show that an increase in the real oil price will lead to a depreciation of the real exchange rate whilst an increase in productivity differential or the real interest rate differential will lead to an appreciation of the real exchange rate. The results of the generalized forecast error variance decompositions show that productivity differential is relatively more important than the real oil price to the real exchange rate determination in Japan. The real oil price has a role in the information set when estimating the real exchange rate. There is a link between commodity and currency world markets. Faster economic growth would lead to appreciation of the real exchange rate. Generally, the real oil price, productivity differential, and the real interest rate differential are important in the real exchange rate determination in an independently floating exchange rate regime and a relatively closed developed economy.

Acknowledgements

The author would like to thank the reviewers of the bulletin for their constructive comments on an earlier version of this paper. All remaining errors are the author's.

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