

Longer Data, Less “CHEER”—Case Study of Yen-Dollar Exchange Rate

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Abstract

This paper compares CHEER approach in both short-run (since 1973) and long-run (since 1870) with the yen-dollar exchange rate. The most important result is that CHEER is valid only in the period when the international capital market is developed enough. Historical data will render the interest rate parity insignificant and thus CHEER will fail. Also, the paper demonstrates that when either PPP or UIP fails, modification of the cointegration variables improves the power of the CHEER test.

Keywords

PPP, UIP, CHEER, Exchange Rate

1. Introduction

The question of exchange rate determination has been the center of research in international economics and finance. In the literature, purchasing power parity (PPP), which was put forth by [1], probably is the first theory to measure the equilibrium exchange rate level. Empirical tests of PPP have been typically based on the investigation of the time series property of the real exchange rate, which can be seen as the residuals from PPP. These test results indicate that PPP may not hold: the failure of PPP in the short run is common. Even in the long run, the validity of PPP is mixed.

The failure of PPP caused many people to raise doubt on the PPP as the model of equilibrium exchange rate. With the great expansion of world financial markets in the past thirty years, some researchers argue that the price levels are not sufficient to capture all the factors causing fluctuations of the exchange rate without taking the world financial markets into account. In terms of balance of

payments, PPP only represents the current account, while the capital account is by and large ignored. For this reason, the exchange rate deviation from PPP is not surprising because of the existence of non-zero interest rate differentials. Accordingly, a model that covers both the purchasing power parity and uncovered interest parity (UIP) is more appropriate to forecast the equilibrium exchange rate. This methodology, therefore, is called the capital enhanced equilibrium exchange rate (CHEER) approach by [2].

The CHEER approach was first proposed by [3] and then developed by [4]. Since then, the CHEER approach has become popular in the study of exchange rates. Extensively studied, the conclusion for CHEER is still mixed: some researchers find supportive evidence while others cannot.¹

Considering the different exchange rates, dissimilar empirical methods and varying data span in CHEER tests, mixed results may not be unusual. Still, it is important to summarize the key characteristics of the current research. Careful review of these papers raises at least two questions. The first question is why the cointegration relationship is often investigated between prices, interest rates and the *contemporaneous*, not the *expected future exchange rate*? Substituting the current exchange rate for the future rate is not in consistency with the CHEER approach because UIP hypothesis describes the relationship between interest rates and expected future exchange rate, not the current rate. Therefore, literally speaking, PPP and UIP are not combined correctly in the papers where the contemporaneous exchange rate is put to test.

IF PPP and UIP are the underlying theoretical framework for CHEER, then we have the second question: why PPP and UIP are not explicitly tested before checking CHEER? Or, equivalently, can the non-rejection of no cointegration be ascribed to the failure of PPP or UIP? This paper shows that either a failure of PPP or UIP does result in non-rejection of no-cointegration. The reason is that the linear sum of error terms in PPP and UIP will not be stationary if exactly one of them fails to hold.² In this case, it is impossible to find evidence supporting the CHEER approach. Modification of the variables under study, however, may increase the possibility of finding cointegration. Thus, an appropriate step in the investigation of whether PPP and UIP hold is essential to improve the power of cointegration analysis.

This paper aims at demonstrating that ignorance of the two above mentioned questions may be the reasons of mixed evidence for CHEER using the Yen/Dollar exchange rate. For the first question, perfect foresight is assumed to circumvent the lack of expectation in UIP testing. The result reveals that this simple modification is not trivial: cointegration among prices, interest rates and the exchange rate would not exist without adding expectations.

¹For positive results, see [5], [6], [7], etc. For the negative results, see [8], [9], [10] [11], and [12], etc.

²Here it is important to note that when both PPP and UIP fail, it becomes possible to find evidence of supporting CHEER. The reason is that the sum of the two nonstationary residuals in PPP and UIP may be stationary because of the interaction of goods market and financial market. In [13], for example, although both PPP and UIP fail, cointegration relationship among prices, interest rates and exchange rate with dollar still exists.

For the second question, this paper explicitly distinguishes short-run and long-run analysis. The short-run analysis consists of monthly data from 1973, while the long-run investigation covers annual data from the year 1870. This different treatment according to data span proves essential, yet in a very unexpected way: although supportive evidence for CHEER is found in the short-run, it does not exist in the long-run. The econometric analysis reveals that this is because the relative interest rates become exogenous in the long run and it does not belong to the exchange rate determination system. The puzzling result can be explained from the development of international capital markets. The short-run analysis covers recent data when capital market becomes as important as the goods market. Most of the time in the long-run, in contrast, does not see well developed international capital market. Because the essence of CHEER approach is to determine the exchange rate through both trade and finance markets, it is not a surprise to see CHEER fail in the period when one market is not well developed.

The remainder of this paper is structured as follows. Sections 2 and 3 analyze the short-run and long-run, respectively. Section 4 summarizes this paper.

2. Short-Run Analysis

2.1. PPP and UIP

Let P_t and P_t^* denote the price levels for the home and foreign country respectively, and S_t represents the nominal exchange rate (foreign price of domestic currency). PPP can be expressed as $P_t = S_t P_t^*$. By changing to lower-case letters to denote the natural logs, it can be rewritten as:

$$s_t = p_t - p_t^*. \quad (1)$$

Traditionally, Equation (1) is referred as the absolute PPP and the relative PPP is its first order difference:

$$\Delta s_t = \Delta p_t - \Delta p_t^*. \quad (2)$$

Tests for PPP refers to the investigation of time series properties of the real exchange rate q_t .

$$q_t = s_t - p_t + p_t^*. \quad (3)$$

Uncovered Interest Parity (UIP) states that one unit of currency should have the same return whether invested in the domestic or the foreign markets at equilibrium. Let I_t and I_t^* denote the domestic and foreign interest rates, respectively, and $E_t(S_{t+1})$ represents the expectation of nominal exchange rate at period $t+1$, then UIP can be written as:

$$1 + I_t = (1 + I_t^*) \frac{E_t(S_{t+1})}{S_t}, \quad (4)$$

or

$$E_t(s_{t+1}) - s_t = i_t - i_t^*, \quad (5)$$

where $s_t = \log(S_t)$, $i_t = \log(1 + i_t)$, and $i_t^* = \log(1 + i_t^*)$. Assuming perfect foresight, $E_t(S_{t+1}) = s_{t+1}$, to test UIP is equivalent to test whether the error term,

$$\epsilon_t^{uip} = (s_{t+1} - s_t) - (i_t - i_t^*), \tag{6}$$

is stationary or not.

This paper studies the yen/dollar exchange rate for three reasons. First, Japan and the US are both large trading countries and their economy has a substantial weight in the world. Second, the yen/dollar exchange rate is among the few main currencies that have historical data, which serves the purpose well. Third, the studies on yen/dollar exchange rate abound, making it easy to compare. The short-run data spans from January 1973 to November 2012, taken on the first day of each month from “DataStream”.³

Figure 1 presents the nominal, real exchange rates and changes in the real exchange rates in the short-run. Figure 2 plots the price and interest rate differentials. September 1985 is tested to be a structural break following the procedures in [14], which is widely believed to be the consequence of the Plaza

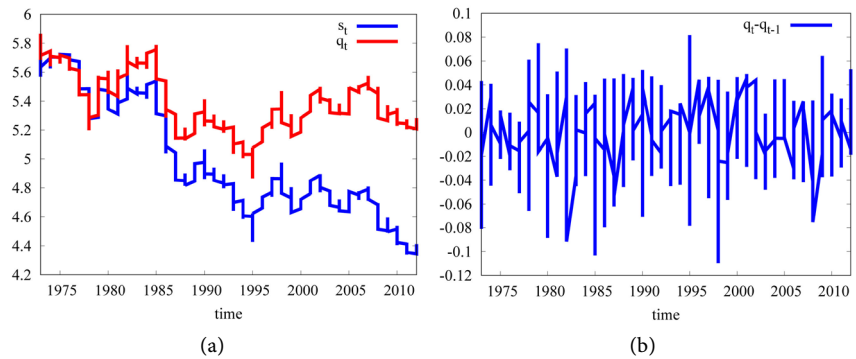


Figure 1. Exchange rates.

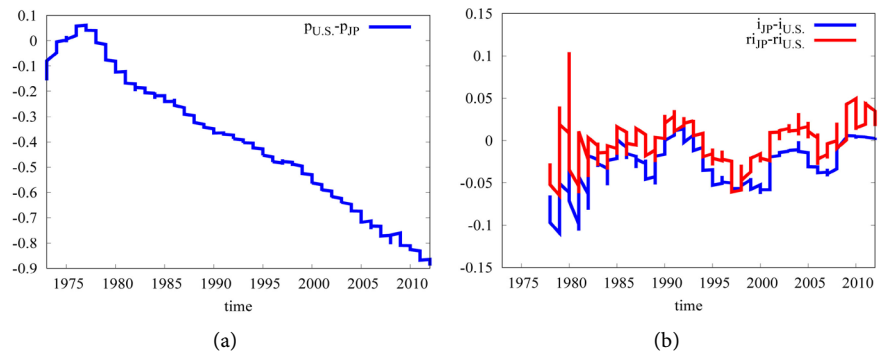


Figure 2. Price and interest rate difference in logs.

³The specific time-series data consist of the following. S : yen/dollar exchange rate (New York market buying rates for the short run; close rates on the last day of each year for the long run); I_{JP} : Japanese nominal interest rate level (euro rates in London market for the short run; 7-year government bond rate for the long run); I_{us} : U.S. nominal interest rate level (euro rates in London market for the short run; 10-year government bond rate for the long run); P_{us} : U.S. consumer price index (CPI); P_{JP} : Japanese CPI; inf_{us} : U.S. inflation level (calculated from “PU”); inf_{JP} : Japanese inflation level (calculated from “PJ”); ri_{us} : U.S. real interest level (calculated from “IU” and “INFU”); ri_{JP} : Japanese real interest level (calculated from “IJ” and “INFJ”).

Accord. In the ADF test, the t -value is -2.2870 , smaller in absolute terms than the 5-percent critical value -2.57 . Similarly, unit root tests for UIP are performed, and the results are summarized in the following.

Table 1 indicates that absolute PPP fails, while relative PPP and UIP hold in the short-run.

2.2. Exchange Rate Determination

The success of relative PPP may lead someone to believe that the price differential is enough to explain the movement of the nominal exchange rate. This section, however, argues that we should discard this optimistic idea. Assume that only the price differential between Japan and U.S. determines the Japanese nominal exchange rate, then we can write out this as the following p_{th} order bivariate vector autoregressive (VAR) system in its standard form:

$$s_t = a_{10} + \sum_{m=1}^p b_{1m} s_{t-m} + \sum_{m=1}^p c_{1m} (p - p^*)_{t-m} + \sum_{m=1}^p d_{1m} (i - i^*)_{t-m} + e_{1t} \quad (7a)$$

$$(p - p^*)_t = a_{20} + \sum_{m=1}^p b_{2m} s_{t-m} + \sum_{m=1}^p c_{2m} (p - p^*)_{t-m} + \sum_{m=1}^p d_{2m} (i - i^*)_{t-m} + e_{2t} \quad (7b)$$

where e_{1t} and e_{2t} are white-noise disturbances.

Equations (7a) and (7b) are called the restricted system in that all the coefficients of interest differential, d_{1m} and d_{2m} are assumed to be zeros. The block exogeneity test, however, reveals that this restriction is binding. The χ^2 distributed test statistics is 50.6849, far exceeding the 1 percent critical value.⁴ Therefore the interest differential is essential in the determination of the exchange rate in the short-run.

The above preliminary tests suggest that CHEER may be more appropriate to forecast the exchange rate in the short-run. Recall that the relative PPP and UIP are:

$$\Delta s_t = \Delta p_t - \Delta p_t^* + \Delta q_t \quad (8a)$$

$$s_{t+1} - s_t = i_t - i_t^* + \epsilon_t^{uip} \quad (8b)$$

Differencing Equation (8b) yields

$$\Delta s_{t+1} - \Delta s_t = \Delta(i_t - i_t^*) + \Delta \epsilon_t^{uip} \quad (9)$$

and substituting Equation (8a) into Equation (9),

Table 1. Summary of the unit root tests.

Variable	DF	PP	ADF
q_t	-2.4356	-2.6500	-2.2870
Δq_t	-15.9500	-15.8303	-10.0338
ϵ_t^{uip}	-8.8310	-8.6866	-5.1553

⁴For lag length p , both SBC and AIC criteria selects 2. The number of restrictions thus in (7a) and (7b) is 6.

$$\Delta s_{t+1} = \Delta(p_t - p_t^*) + \Delta(i_t - i_t^*) + \eta_t \tag{10}$$

where $\eta_t = \Delta q_t + \Delta \epsilon_t^{uip}$.

Equation (10) is the model of nominal exchange rate determination in the short-run. It states that the exchange rate is jointly determined by the price and interest rate differentials: the increases in either price or the interest rate differentials will cause the future nominal exchange rate to depreciate. For example, if a country is suffering higher inflation or sharp interest rate increasing, its exchange rate will depreciate.

It is worth noting that, compared with normal CHEER approach, which usually searches cointegration directly between s_t , $p_t - p_t^*$ and $i_t - i_t^*$, Equation (10) has two modifications. One is that it is of first-order difference, and the other is that it involves expectations, though the expectations here are assumed to be perfect. Here we will show that the two modifications are necessary because we cannot find cointegration with either modification absent. To see this, consider the following three models:

Model 1: $s_t, p_t - p_t^*, i_t - i_t^*$

Model 2: $s_{t+1}, p_t - p_t^*, i_t - i_t^*$

Model 3: $\Delta s_{t+1}, \Delta(p_t - p_t^*), \Delta(i_t - i_t^*)$.

Model 1 is the most often seen practice in most papers, which investigate the relationship between the exchange rate, price and interest rate differentials. Model 2 adds expectation, which comes from the UIP hypothesis. Model 3 is further modified by adding a first-order difference, which is based on the empirical tests of PPP and UIP. The results of the cointegration tests are summarized in **Table 2**. Comparing the results in **Table 2**, we conclude that the effect of the two modifications is significant. Only model 3, *i.e.*, the model with expectation and first-order difference can yield the cointegration relationship.⁵

2.3. The VAR Analysis

Model 3 implies that the short-run model can be presented by a structural VAR system

$$\Delta s_{t+1} = a_{10} + \sum_{m=0}^p b_{1m} \Delta s_{t+1-m} + \sum_{m=0}^p c_{1m} \Delta(p - p^*)_{t-m} + \sum_{m=0}^p d_{1m} \Delta(i - i^*)_{t-m} + e_{1t} \tag{11a}$$

Table 2. Cointegration tests.

$s_t, p_t - p_t^*, i_t - i_t^*$			$s_{t+1}, p_t - p_t^*, i_t - i_t^*$			$\Delta s_{t+1}, \Delta(p_t - p_t^*), \Delta(i_t - i_t^*)$		
Eigenv	Maxλ	trace	Eigenv	Maxλ	trace	Eigenv	Maxλ	trace
0.0679	20.84	39.78	0.0617	18.85	40.37	0.1487	47.51	87.52
0.0483	14.66	18.95	0.0562	17.11	21.52	0.0817	25.14	40.01
0.0144	4.29	4.29	0.0148	4.40	4.40	0.0492	14.88	14.88

⁵At the 5% level, *Maxλ* and Trace for $H_0 = 0, 1, 2$ are 21.07, 14.90, 8.18 and 31.52, 17.95, 8.18 respectively. When *Maxλ* and Trace contradicts each other, we select stricter criteria to pin down the number of cointegration vectors.

$$\Delta(p - p^*)_t = a_{20} + \sum_{m=0}^p b_{2m} \Delta s_{t+1-m} + \sum_{m=0}^p c_{2m} \Delta(p - p^*)_{t-m} + \sum_{m=0}^p d_{2m} \Delta(i - i^*)_{t-m} + e_{2t} \tag{11b}$$

$$\Delta(i - i^*)_t = a_{30} + \sum_{m=0}^p b_{3m} \Delta s_{t+1-m} + \sum_{m=0}^p c_{3m} \Delta(p - p^*)_{t-m} + \sum_{m=0}^p d_{3m} \Delta(i - i^*)_{t-m} + e_{3t} \tag{11c}$$

Based on the VAR system (11a), (11b) and (11c), the Granger causality test can be performed. The F-test and the corresponding significance level are reported in **Table 3**.

Table 3 shows that Δs_{t+1} Granger causes only itself, $\Delta(i_t - i_t^*)$ also roughly Granger causes only itself, while $\Delta(p_t - p_t^*)$ Granger causes all the three variables. To further identify the different roles $\Delta(p_t - p_t^*)$ and $\Delta(i_t - i_t^*)$ play in the model of exchange rate determination, decomposing the forecast error variance is conducted. Based on the VAR system (11a), (11b) and (11c), the 1-step ahead through 24-step ahead forecast errors is calculated. The forecast error decomposition implies that $\Delta(i_t - i_t^*)$ explains more of the movements of Δs_{t+1} than that of $\Delta(p_t - p_t^*)$ in all the time horizons. In the 6 month ahead forecast, for example, $\Delta(p_t - p_t^*)$ explains 0.217 percent of Δs_{t+1} , while $\Delta(i_t - i_t^*)$ explains 0.437 percent.

It is worth noting that the exchange rate determination model is derived from the economic theories and the differenced variables make it a little difficult to grasp the real effects since differencing tends to smooth the various shocks. Moving away the difference in (10) to set up a VAR system containing s_{t+1} , $(p_t - p_t^*)$ and $(i_t - i_t^*)$ and calculate the forecast error did not change the conclusion: $\Delta(i_t - i_t^*)$ explains more of the movements of Δs_{t+1} than that of $\Delta(p_t - p_t^*)$.

Moreover, considering the interest rate differential is small in value and differencing it may cause it to appear white noise, its effect tends to be underestimated in (10).⁶ Granger causality test between s_{t+1} , $(p_t - p_t^*)$ and $(i_t - i_t^*)$ yields a different result, as is shown in **Table 4**.

As indicated from **Table 4**, in the 5 percent significance level, the price differential $(p_t - p_t^*)$ Granger-causes itself and the interest rate differential $(i_t - i_t^*)$; $(i_t - i_t^*)$ Granger-causes all the three variables. It explains 10.296 percent of s_{t+1} at the 12-lag ahead forecast, leaving $(p_t - p_t^*)$ only account for

Table 3. Summary of the Granger causality tests in the short-run.

variable	Δs_{t+1}	$\Delta(p_t - p_t^*)$	$\Delta(i_t - i_t^*)$
Δs_{t+1}	22.5773	0.0000	0.4155
$\Delta(p_t - p_t^*)$	5.8880	0.0030	6.8310
$\Delta(i_t - i_t^*)$	2.0701	0.1275	0.5540

⁶The mean of $\Delta(i_t - i_t^*)$ is 0.000201.

Table 4. Summary of the Granger causality tests.

variable	s_{t+1}	$(p_t - p_t^*)$		$(i_t - i_t^*)$		
s_{t+1}	1277.61	0.000	0.6698	0.7804	2.2332	0.0101
$(p_t - p_t^*)$	1.2960	0.2185	21390.95	0.0000	2.4276	0.0048
$(i_t - i_t^*)$	1.8415	0.0400	2.8121	0.0010	320.3485	0.0000

0.54 percent in the same period. Therefore, the interest differential seems more essential in the determination of exchange rate movement in the short run.

3. Long-Run Analysis

The long-run data from the year 1870 to 2012, consisting of the exchange rate, the CPI index and the long-term interest rates for the US and Japan.⁷ **Figure 3** depicts the exchange rates and **Figure 4** shows the price and interest rate differentials. [14] tests reveal that from 1870 to 2012, two structural breaks occurred. One is the year 1945, in which the yen depreciated more than 200 percent (from 4.29 to 15). The other notable break is the year 1970, in which the yen began to appreciate sharply due to the oil shock. We next proceed to test PPP and UIP, the same as the analysis for the short run. ADFs test of \hat{q}_t and ϵ_t^{uip} yield the statistics of -2.93 and -3.30 , respectively. Both statistics exceed the 5-percent critical value of -2.88 . Therefore, both PPP and UIP hold in the long-run. Substitute s_t in Equation (1) into (5), and assuming perfect foresight, the long-run exchange rate model can be written as:

$$s_{t+1} = (p_t - p_t^*) + (i_t - i_t^*) + \xi_t \tag{12}$$

where ξ_t is the sum of errors from PPP and UIP. The Johansen test results of Equation (12) are summarized in **Table 5**.

Table 5 indicates that the null hypothesis of no cointegration vector among s_{t+1} , $(p_t - p_t^*)$ and $(i_t - i_t^*)$ cannot be rejected either by the *Maxλ* or Trace statistics. Therefore, the CHEER approach fails in the long run.

To further understand the internal mechanism, a VAR system consisting of s_{t+1} , $(p_t - p_t^*)$ and $(i_t - i_t^*)$ are set up, with the following two questions to investigate. The first is to see which is the driving force in the exchange rate determination, $(p_t - p_t^*)$ or $(i_t - i_t^*)$? The second question is, after knowing the driving force, should the other one be excluded in the exchange rate determination system?

Consider the following VAR,

$$s_{t+1} = a_{10} + \sum_{m=0}^p b_{1m} s_{t-m} + \sum_{m=0}^p c_{1m} (p - p^*)_{t-m} + \sum_{m=0}^p d_{1m} (i - i^*)_{t-m} + e_{1t} \tag{13a}$$

$$(p - p^*)_t = a_{20} + \sum_{m=0}^p b_{2m} s_{t-m} + \sum_{m=0}^p c_{2m} (p - p^*)_{t-m} + \sum_{m=0}^p d_{2m} (i - i^*)_{t-m} + e_{2t} \tag{13b}$$

⁷Long-term interest rates are U.S 10 year government bond yield and Japanese 7 year government bond yield. The maturities are different because no other long-run rate is available.

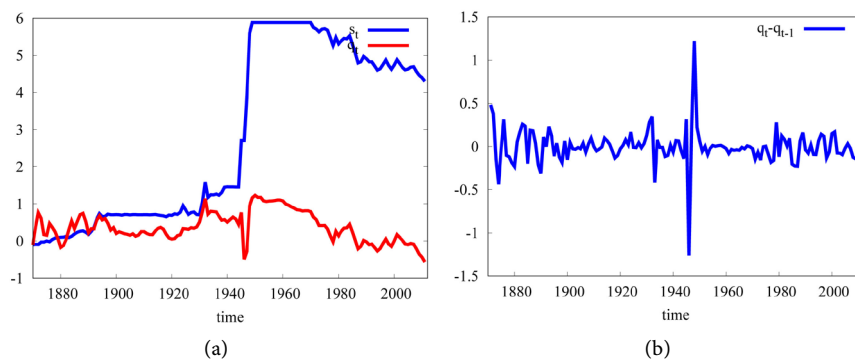


Figure 3. Exchange rates.

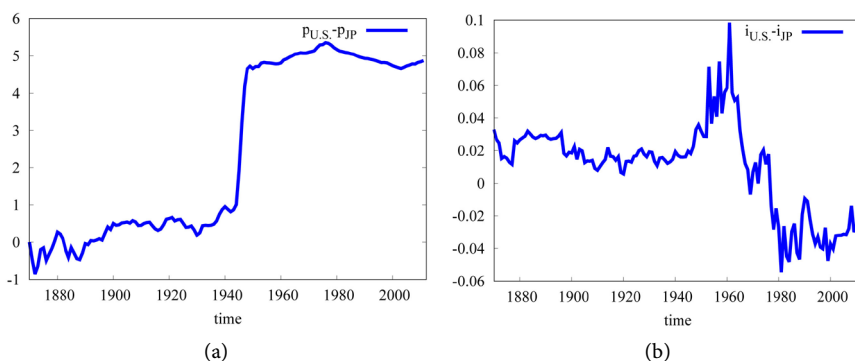


Figure 4. Price and interest rate difference in logs.

Table 5. Summary of the Johansen cointegration test in the long-run.

Eigen ν	Max λ	Trace	$H_0 : r$	$p - r$	Max λ_{95}	Trace $_{95}$
0.1286	18.19	34.31	0	3	21.07	31.52
0.051	10.86	16.12	1	2	14.90	17.95
0.0192	5.26	5.26	2	1	8.18	8.18

$$(i - i^*)_t = a_{30} + \sum_{m=0}^p b_{3m} s_{t-m} + \sum_{m=0}^p c_{3m} (p - p^*)_{t-m} + \sum_{m=0}^p d_{3m} \Delta(i - i^*)_{t-m} + e_{3t} \quad (13c)$$

where a , b , c and d are parameters, and e_{it} ($i = 1, 2, 3$) are error-terms.

Granger causality tests are performed to answer the first question. The joint F-statistics and the significance levels of system (13a) through (13c) are reported in Table 6.⁸ Table 6 indicates that at 5 percent significance level, s_{t+1} and $(p_t - p_t^*)$ both Granger-cause themselves and each other; $(i_t - i_t^*)$ Granger-causes only itself and is not Granger-caused by any of the other two. These results imply that the interest rate differential $(i_t - i_t^*)$ is not an endogenous variable in the system of exchange rate determination.

To answer the second question, the block exogeneity test, which is similar to the method in (7a) and (7b) is conducted.⁹ The likelihood ratio statistics is

⁸Both AIC and SBC select the lag length 3.

⁹Here the number of restrictions is 10 (lag 0, 1, 2, 3, 4 in each equation) and the unrestricted model contains 12 coefficients.

Table 6. Summary of the Granger causality tests in the long-run.

variable	s_{t+1}	$(p_t - p_t^*)$	$(i_t - i_t^*)$
s_{t+1}	102.1002	0.000	13.4854
$(p_t - p_t^*)$	17.1311	0.0000	174.2864
$(i_t - i_t^*)$	2.3350	0.0770	1.6913

8.1749 with significance level 0.6117, less than the 5 percent critical value of 18.3074. Therefore, the null hypothesis of exclusion of the interest rate differential cannot be rejected.

Both the Granger causality tests and the block exogeneity test indicate that the interest rate differential, $(i_t - i_t^*)$, is trivial and CHEER hypothesis fails in the long run. The failure of CHEER in the long run seems puzzling here because we have found cointegration in the short run and many economic hypotheses tends to hold better in the long run. [15], for example, is unable to find cointegration in the short run but finds cointegration in the long run.¹⁰ We can explain the puzzle from the history of financial markets. Financial markets did not develop well until the past 30 years and its role in the exchange rate determination is not apparent if we view it in a very long data span. If we test CHEER hypothesis using the recent data, the interest rate differential tends to become more significant because of its notable size. In short, the 140 years is too long and the effect of financial market in exchange rate determination in recent years is “diluted”.¹¹

4. Conclusion

This paper tests CHEER approach both in the short-run and the long-run with the yen/dollar exchange rate. The main result is that CHEER approach is only supported by the short-span data. Actually, it is revealed that the interest rate differential plays a more important role in the exchange rate determination. When examined in the historical data, the price level difference alone becomes sufficient to explain the exchange rate movement and CHEER fails. The reason behind this is the different stage of the international financial market. Since the core idea of CHEER is to determine the exchange rate from both goods market and financial market, it is not a surprise that it will fail during the period when at most times, the international financial market is under-developed, compared to the goods market.

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¹⁰[15] researched on yen/dollar case and found no causality between prices and exchange rates in the short run. However, causality is found running from relative prices to exchange rates along with interest rates in the long run.

¹¹The forecast error decomposition also suggests that the price differential $(p_t - p_t^*)$ is the dominant factor in the determination of s_{t+1} . In the 5-lag ahead forecast horizon, $(p_t - p_t^*)$ explains 8.495 percent of the error of s_{t+1} , while $(i_t - i_t^*)$ explains 0.199 percent.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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