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Long-run implications of the covered interest rate parity condition: evidence during the recent crisis and non-crisis periods

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Structural Breaks in Forward Premiums and Implications for the Covered Interest Rate Parity Condition: Evidence during Recent Crisis and Non-Crisis Periods

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Abstract

This paper analyzes the importance of structural shifts in forward premiums in foreign exchange markets and implications for the covered interest rate parity condition (CIRP) condition. Considering a wide range of countries and contract periods and taking into account cross-sectional correlations and heterogeneities in nonstationary environments, we confirmed mixed evidence of stationary forward premiums. Further analysis suggests that the nonstationary element is attributable to regime shifts which are closely associated with the effects of the Lehman Shock and changing monetary policies. However, these effects can be captured by interest rates, leaving the covered CIRP as a valid economic concept, at least in the long-run.

Keywords: Panel unit root tests, structural shifts, forward premiums, Lehman Shock

JEL classification: F31, C12

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1 Introduction

Forward exchange rates have increasingly been used by investors in order to reduce market risks. Therefore, many researchers have analyzed the forward premium (fp_t) which can be expressed in natural logarithmic form as a difference between the jth-period maturity forward rate (f_t^j) and the spot rate (s_t) at time t (i.e., $fp_t = f_t^j - s_t$, known as a forward premium/discount and referred to as a forward premium hereafter). Among other factors, previous studies identified that the forward premium is caused by market liquidity (Fukuta and Saito 2002) and changes in macroeconomic conditions (e.g., Nagayasu 2011) including interest rate differentials following the covered interest rate parity (CIRP) condition. When these factors yield a persistent effect on the premium, the forward premium may follow a nonstationary process. This has a profound implication for international finance studies since given that changes in spot exchange rates were frequently reported to be stationary in previous studies, the nonstationary forward premium has been pointed out as a source of the forward rate puzzle (Barnhart et al 1999),[1] one of the outstanding issues in international finance, first brought to light by Fama (1984).

Indeed, while many theoretical models rely on the economic assumption of the stationary forward premium, previous empirical studies have provided quite mixed results.[2] For example, Baillie and Bollerslev (1994) used the fractionally integrated method to study forward premiums for Canadian, German and UK exchange rates against the US dollar. They showed that premiums for Germany and the UK follow a stationary process and that for Canada the nonstationary. Similarly, Liu and Maynard (2005) confirmed uncertainty regarding the stationarity of the premium using the currencies of Australia, Canada, France, Germany, Japan and UK against the US dollar. The stationarity of premiums is also sensitive to contract maturities; evidence of stationarity is reported only for short-term premiums (Nagayasu 2011). Furthermore, using observations from the recent crisis, a violation of the CIRP has

[1] The study on forward premiums is related to the analysis of the unbiasedness of forward rates. The latter can be examined by testing whether forward rates are equal to future spot rates (i.e., $f_{jt} = s_{t+j}$). Thus, what is different from the forward premium study is that the future spot rate (at time $t + j$) is used rather the present spot rate (i.e., s_t). Recently Pippenger (2011) argued that the forward rate puzzle arises from a misspecification of the standard statistical model to test the theoretical model.

[2] Engel (1996) summarizes empirical studies related to forward premiums. An analysis of the forward rate unbiasedness hypothesis also raises mixed evidence. For example, Hai et al (1997) studied a long-run relationship between the forward and future spot exchange rates for advanced countries relative to the US dollar. Their cointegraton tests generally support a stationary relationship by imposing the theoretical parameter restriction. In contrast, Ho (2003) studied the unbiasedness of forward rates in the panel context using the nonstationary Seemingly Unrelated Regression (SUR) method and concluded that the unbiasedness hypothesis does not hold for advanced countries.

been discussed recently by a number of researchers (e.g., Coffey et al. 2009, Levich 2011).

Against this background, we shall first of all analyze the stationarity of the forward premiums of a variety of countries, using the US dollar and Euro as numeraire currencies, in both time-series and panel data contexts. Then, in the presence of nonstationarity in the premiums, we proceed to examine whether structural shifts caused by the recent financial crises (e.g., the Lehman Shock) contribute to this outcome and become a source of violation of the CIRP.

Thus, this paper makes two contributions to the literature. First, by taking account of possible shifts in forward premiums, we attempt to find reasons for their possible nonstationarity using the recent data. Previous studies seem to point out the importance of shifts. For example, Jeon and Seo (2003) reported a breakdown of a cointegrated relationship between spot and forward exchange rates during the 1997 Asian crisis but an immediate recovery soon after this event. Similarly, Sakoulis et al. (2010) raised evidence of structural breaks in forward premiums of advanced countries during the period 1978-1998. In this connection, we employ panel unit root tests which have more statistical power than univariate tests and take account of premium-specific regime shifts. These techniques will be applied to our data set which comprises among many others one-week forward premiums which have not been intensively investigated before despite the fact that most forward contracts are short-term with a typical maturity length of less than one month (see next section).

Secondly, previous studies analyzed the forward-spot relationship relative to the US dollar, but they seldom asked any questions about the potential effect of a numeraire currency. Probably MacDonald and Moore (2001) is one exception which considered different numeraire currencies; the Deutschmark (DM) and US dollar. They reported that stability of the premium is sensitive to their choice and is obtained only when the dollar is used as a numeraire.

2 The Description of the Exchange Rate Data

According to the survey conducted by the Bank for International Settlements (BIS 2010), the foreign exchange market has grown rapidly over the years, and gross turnover reached US$ 3,981 billion in 2010—a 20 percent increase since 2007. Out of this total turnover, US$ 475 billion was related to outright forwards when classified by instruments. In terms of the distribution of global foreign exchange market turnover, the US dollar has been a dominant currency (85 percent in 2010), followed by the Euro (39 percent), the Japanese yen (19 percent), and so on.[3] The turnover for outright forwards can also be classified in terms of maturity length; 46 percent of outright forwards have a maturity of up to seven days in 2010, and 52 percent a maturity from 7 days to one year. Thus, the majority of outright forwards is characterized as short-term in nature and is denominated against the US dollar. This trend has not changed since 1998 when survey data became available.

Against this background, we gather monthly data on forward and spot exchange rates - with a maturity length of 1 week and 1, 2, 3, 6, 9 and 12 months - from DataStream. These rates are denominated against the US dollar or Euro, which are the most important currencies for international trade, and cover the sample period from 1999M1 to 2011M3. The beginning of this period is determined by the timing of the introduction of the Euro. Due to the availability of forward exchange rates, we consider advanced countries; namely, Australia, Canada, Czech Republic, Denmark, New Zealand (NZ), the United Kingdom (UK), Hong Kong (HK), Japan, Norway, Singapore, Sweden, Taiwan, the United States (US) and the Eurozone.[4] Prior to formal investigation, we shall next present some summary statistics.

Table 1 summarizes the average of forward premiums which are calculated as $fp_t = f_t - s_t$ (as defined in the Introduction). For premiums with the US dollar as a numeraire, about half - 7 - countries have a negative one-week premium and the rest a positive premium. For those with the Euro as a numeraire, the number of negative premiums drops slightly to just 4 cases. Furthermore, the size of premiums tends to increase along with the maturity length. In particular, the average of one-year premiums relative to the Euro is about 60 times larger than that of the one-week premium. Thus, although we do not carry out a further detailed analysis, it follows that effects of, for example, market illiquidity, are more significant in the long-term premium.

Table 2 lists the standard deviation of forward premiums for each country and contract maturity. Generally speaking, volatility is higher in long-term premiums. For example, a one-year premium relative to both the US dollar and Euro is about 38 times more volatile than a one-week premium. Therefore, higher volatility for the longer-maturity premium seems to be the case regardless of the country and/or numeraire currency.

In addition to these summary statistics, we have checked the cross-section dependence of our premiums. The Breusch-Pagan test is carried out to test the null

[3] The total share of currencies used in the foreign exchange rate market is 200% since each transaction involves two currencies.

[4] Forward rates relative to the UK pound are also available from DataStream; however, they are not available for all our countries or contract maturities during our sample periods.

hypothesis of the independence of forward premiums across countries. The test exploits residual correlations from the seemingly unrelated regression (SUR) estimators, and this statistic (Table 3) is distributed as χ^2. Corresponding p-values suggest that this null is strongly rejected in all cases. This result likely reflects that a panel of premiums is based on the same numeraire currency (i.e., either the US dollar or Euro) and thus they share common economic shocks. Furthermore, the cross-section dependence may arise from the mechanism of modern foreign exchange markets which are closely linked through Information Technology (IT), and whereby any relevant information will spread instantly to other markets. In short, these results suggest that it is important to consider contemporaneous correlations when analyzing the behaviors of the premiums.

3 Statistical Method

In order to analyze the stationarity of forward premiums and identify significant historical events, we employ several types of unit root tests that can detect structural breaks in data. A stationarity test was originally developed in order to check the time-series properties of univariate data (Dickey and Fuller 1979). Since then, much progress has been made in a number of directions, and Levin and Lin (1992) is one such example which proposed a panel unit root test. Since researchers often face limited time-series observations, it is said that statistical power will be enhanced by incorporating cross-sectional information. Here the stationarity of forward premiums will be examined using the Lagrangian Multiplier (LM) based panel unit root test (Im et al 2005) which is an extension of the LM unit root test for univariate data (Lee and Strazicich 2003, 2004) and allows us to estimate endogenously the premium-specific timing of structural breaks.

More specifically, Im et al (2005) have proposed a panel unit root test with a level shift in order to examine the null hypothesis that all series are unit roots against the alternative that at least one of them is stationary. Since breaks are considered under both null and alternative hypotheses, this is not a test to evaluate the presence of breaks. However, obtaining evidence of both 1) nonstationary premiums without consideration of level shifts and 2) stationary premiums with shifts becomes a sign that such breaks and events are significant. Here, we shall utilize this information in order to identify historical events relevant to the nonstationarity of the premiums.

For premiums for countries ($i = 1, \ldots, N$) and time ($t = 1, \ldots, T$), the LM panel data approach with a level shift for each premium (fp_{it}) can be summarized as follows.

$$
\begin{aligned}
fp_{it} &= z_{it} + x_{it} \\
z_{it} &= \gamma_{1i} + \gamma_{2i}t + \delta_i D_{it} \\
x_{it} &= \rho_i x_{it-1} + \varepsilon_{it}
\end{aligned} \tag{1}
$$

where $D_{it} = 0$ when $t \leq T_{Bi}$ and $D_{it} = 1$ when $t \geq T_{Bi}+1$. The residual ε_{it} follows a normal distribution with zero mean and variance σ_i^2, and the timing of breaks are expressed as T_B. Thus this model allows a level shift which can be different among premiums. The null hypothesis of the unit root against the alternative of some stationary variables will be tested by $\rho_i = 1$. In this case, equation (1) suggests that x_{it} and thus fp_{it} follows the unit root process given that ε_{it} is stationary. This becomes evidence of a persistent discrepancy between the forward and spot exchange rates.

Alternatively, this null can be tested by $\beta_i = 0$ where $\beta_i = -(1-\rho_i)$ in the following equation which can be obtained from equation (1):

$$
\Delta fp_{it} = \beta_i fp_{it-1} - \beta_i \gamma_{1i} + [1 - (\beta_i + 1)(t-1)]\gamma_{2i} + (\Delta D_{it} - \beta_i D_{it-1})\delta_i + \varepsilon_{it} \tag{2}
$$

where Δ is a difference term. The parameters will be estimated by the maximum likelihood method based on the following log likelihood function.

$$
\ln L = \sum_{i=1}^{N} (-0.5T \ln 2\pi\sigma_i^2 - 0.5\sigma_i^{-2}\mathrm{SSE}_i) \tag{3}
$$

where $\mathrm{SSE}_i = \sum_{t=1}^{T} \{\Delta fp_{it} - \beta_i fp_{it-1} + \beta_i \gamma_{1i} - [1-(\beta_i+1)(t-1)]\gamma_{2i} - (\Delta D_{it} - \beta_i D_{it-1})\delta_i\}^2$. The location of a shift will be determined for each premium and will be estimated on the basis of equation (3).

The LM panel unit root statistic can be calculated as per the approach of Im et al (2003). The basic specification can be expressed as:

$$
\begin{aligned}
\Delta fp_{it} &= \gamma_{2i} + \delta_i \Delta D_{it} + \beta_i S_{it-1} + \textstyle\sum_{j=1}^{p_i} \rho_{ij} \Delta S_{it-j} + \varepsilon_{it} \\
S_{it-1} &= fp_{it-1} - \gamma_{2i}(t-1) - \delta_i D_{it-1}
\end{aligned} \tag{4}
$$

In order to evaluate the null $\beta_i = 0$, the cross-sectional average of t statistic ($\bar{t}_{LM,NT}(p)$) will be calculated as:

$$
\bar{t}_{LM,NT}(p) = \frac{1}{N} \sum_{i=1}^{N} t_{LM,iT}(p_i) \tag{5}
$$

where $t_{LM,iT}(p_i)$ is obtained from each premium equation. The panel LM statistic, which is asymptotically distributed normal with zero mean and unit variance, can be constructed while making adjustments to the mean and variance:

$$\Gamma_{LM}(p) = \frac{\sqrt{N}\left\{\bar{t}_{LM,NT}(p) - \frac{1}{N}\sum_{i=1}^{N}[\iota_{LM,T}(p_i)]\right\}}{\sqrt{\frac{1}{N}\sum_{i=1}^{N} V[\iota_{LM,T}(p_i)]}} \sim N(0,1)$$

where $E[.]$ and $V[.]$ are the expected value of the mean and variance respectively which are obtained by stochastic simulations (Im et al 2005). This statistical distribution will not be affected by the presence or location of the level shift since ΔD_{it} (rather than its level) is used here. Needless to say, this test becomes the standard panel unit root test to examine the null of nonstationarity when D_{it} is dropped from the specification.

For operational purposes, the cross-sectional average of the premiums is removed from original data consistent with the theoretical assumption of the test. This data transformation is necessary since we have obtained evidence of significant cross-sectional correlations in our data (Table 3). In addition, following the suggestion of Im et al (2005), to adjust autocorrelation in equation (4) the lag length is determined by the general-specific approach for each premium with a maximum of 3 lags, and the grid search method is applied to the trimmed sample period (from $0.1 * T$ to $0.9 * T$) in order to find optimal breakpoints. This truncation of data essentially excludes most observations relevant to the Greek debt crisis.

4 Empirical Results

4.1 Forward premium

Using the statistical method summarized in the previous section, we examine if the forward premiums are stationary. In short, the panel test suggests a persistent departure of the forward exchange rate from the spot rate without consideration of major financial crises. But evidence of the stationarity of the forward premium is found once the effects from crises are taken into account. In particular, level shifts are indeed important for understanding the behaviors of the forward premiums: regardless of the maturity length, strong evidence of at least one stationary premium is obtained once level shifts are considered.

More specifically, first, LM statistics (Im et al. 2005) are calculated based on the abovementioned approach without a level shift dummy (D). Table 4 shows that there is evidence of stationary premiums only for a one-week maturity. For the rest, we failed to reject the null hypothesis. The stationarity (nonstationarity) of the shorter (longer) premiums is consistent with Nagayasu (2011) which assumed no structural break in the Asia-Pacific premiums. Needless to say, evidence of structural shifts and the nonstationarity of premiums does not indicate violation of the CIRP. As long as interest rate differentials have the same time-series characteristics and there is cointegration between premiums and interest rate differentials, the CIRP is a valid equilibrium concept.

However, when level shifts are considered, we are able to obtain evidence in favor of stationary premiums for all maturity lengths in the panel data context, and this general conclusion is not affected by the number of shifts (i.e., one or two shifts) in the test. Given the different conclusions, from these analyses, with and without D, we regard these shifts as a significant factor influencing the behaviors of forward premiums. Thus, unlike the Asian crisis (Jeon and Seo 2003), these historical events generated a persistent effect on the forward premiums.

Since the alternative hypothesis of the panel LM test is that some premiums are stationary, this test does not give us any information about which series are stationary. Therefore, in order to identify them, we carry out the univariate LM test (Lee and Strazicich 2003, 2004) which is a basis for the panel unit root test (Im et al. 2005) and assumes one or two breaks for each series (Tables 5 and 6 respectively).[5] The results from our univariate analysis are consistent with those from the panel LM test with regime shifts. There is evidence of stationarity for a majority of premiums using the conventional statistical level.

Furthermore, in contrast to previous studies, our results from the unit root test are not found to be very sensitive to the numeraire currency. MacDonald and Moor (2001) found cointegration for the forward premium against the US dollar but not for the DM premium. They interpreted the lack of cointegration for the DM premiums as evidence of the lack of credibility of the ERM target zone. In this connection, our results suggest the strength of the Euro relative to the DM.

4.2 Identification of break-dates

For illustrative purposes, the break-dates identified by the panel test with one shift are classified by year (Figure 1).[6] It shows the occurrence of structural shifts at different time periods, but the shift took place most often in the year 2008 regardless of the numeraire, which coincides with the year of the Lehman Shock. A combination of the occurrence of shifts in years 2008 and 2009 to include both the immediate effects and the aftershocks of the Lehman Brothers bankruptcy suggests that about

[5] This study considers one and two shifts since Lee and Strazicich (2003, 2004) developed an LM test with a maximum of two level shifts.

[6] The panel test with 2 shifts also shows a similar distribution of potential breaks.

30 percent of premiums relative to the US dollar identified these break-dates. This proportion increases slightly for the premiums relative to the Euro. Based on our previous results, although there are a number of other minor breaks in this figure, consideration of one or two shifts is adequate to alter the result of the panel unit root test.

Then what caused the shifts in the forward premiums? The timing of shifts may reflect changes in US monetary policy which has been discussed as very influential over other economies. In response to a higher than expected increase in inflation caused by a hike in energy and commodity prices worldwide, the US short-term interest rate (the federal fund rate) started to increase from June 2004, raising worries about future uncertainty among investors. Furthermore, in order to facilitate financial stability and US economic recovery, aggressive accommodative monetary policies were implemented leading the federal fund rate to less than one percent in October 2008. Note that Sakoulis et al. (2010) also interpreted shifts as monetary shocks in their study on the forward rate unbiasedness hypothesis.

In order to obtain some statistical evidence of links between the timing of shifts in forward premiums and these historical events, we conduct a stability test for data on the federal fund rate, the world commodity price (S&P GSCI commodity total return) and the US house price index (Case-Shiller home price index, 10-city composite), all from DataStream. Two tests (Andrews-Quandt and Andrews-Ploberger) are employed to analyze the null hypothesis of no shift in the data. Table 7 shows clear evidence of shifts in the data, and the timing of the shift is found to be 2008 for the commodity price and the federal funds rate although the former is statistically insignificant. A shift-date of 2006, when the sub-prime loan problem became apparent in the US, is identified by house price data. Therefore, among these three variables, the interest rate seems to be most closely associated with breaks in the forward premiums, and supports our view that the shifts are related to monetary policies and to the effects of the Lehman Shock.

4.3 Implications of the Structural Shifts in Forward Premiums for the CIRP

Do the recent economic and financial crises affect the CIRP relationship as well? In order to establish a more solid relationship between forward premiums and interest rates which seem to capture the effect of the Lehman Shock and changes in monetary policies, we analyze the CIRP condition. Previously, Taylor (1989) raised evidence of profitable opportunity during periods of turbulence in the 1960s and 1970s but no such evidence during the calm periods. Thus large and persistent effects of financial crises may break down the cointegration relationship in the CIRP. In contrast, given the fact that premiums are nonstationary without structural breaks, cointegration between premiums and interest rates suggests the presence of co-breaking where structural breaks occur in each data at a similar time and deviation from this condition vanishes over time.

In this connection, we shall examine the standard CIRP specification which links forward premiums and interest rate differentials ($Int = r - r^*$ where r is a nominal interest rate and $*$ denotes a foreign rate) for country i and time t. The panel cointegration test (Westerlund 2007) is used with the bootstrap method which is discussed as lessening bias from cross-section dependence. He demonstrates that this test is more powerful and has better size accuracy than other panel tests (e.g., Pedroni 2004).

Using market interest rates (with a three-month maturity) downloaded from DataStream, Table 8 shows strong evidence in favor of the CIRP; the null hypothesis of no cointegration is rejected in all cases by P_α test statistics.[7] This test examines an adjustment coefficient of the error correction terms in the panel data context, and thus like a time-series analysis the large negative test statistic becomes evidence against the null. Since the alternative hypothesis of P_α is that all pairs of the CIRP relationship are cointegrated, a rejection of this null implies that the nonstationary element of the forward premiums and that of the interest rates are cointegrated.

The error correction model can generally be expressed without deterministic terms as:

$$\Delta\widetilde{fp}_{it} = \widehat{\alpha}_i fp_{it} - \lambda_i Int_{it} + \sum_{j=1}^{p_i} a_{ij}\Delta ft_{it-j} + \sum_{j=1}^{p_i} b_{ij}\Delta Int_{it-j} \qquad (6)$$

where $\lambda_i = \widehat{\alpha}_i\beta_i$, β_i being a cointegrating vector, Δx indicates the first difference of variable x, and $\widetilde{fp}_{it}$ is an estimated value of the forward premium based on equation (6). Then the test statistic can be calculated as:

$$P_\alpha = T\widehat{\alpha}$$

where the common error correction term $\widehat{\alpha}$ is:

$$\widehat{\alpha} = \frac{\sum_{i=1}^{N}\sum_{t=2}^{T}\frac{1}{\widehat{\alpha}_i(1)}\widetilde{fp}_{it-1}\Delta\widetilde{fp}_{it}}{\left(\sum_{i=1}^{N}\sum_{t=2}^{T}\widetilde{ft}_{it-1}^{2}\right)}$$

[7]For presentation purposes, Table 8 includes the results for one week premiums, some of which are found to be stationary in the unit root test (Table 4).

Westerlund (2007) also shows the derivation of standard error for this statistic.

Our test result confirms that the effects of a structural break in the forward premiums can be captured by interest rates. It follows that the risk premiums (i.e., the residual of the CIRP) are stationary and thus do not have a permanent impact on the CIRP relationship. Therefore, this study provides evidence in favor of the CIRP and suggests that recent concerns about a violation of the CIRP are expected to be short-lived. This is an issue not touched upon in recent research (e.g., Coffey et al 2009, Levich 2011) which pointed out the significant increase in the credit and counterparty risk in the recent sample period.

Finally, the parameters of the CIRP are estimated by the Dynamic OLS method (Kao and Chiang 2000). While dynamic OLS estimators impose homogeneity parameter restrictions, they are discussed as being less biased than those of the OLS or Fully-Modified OLS which can be constructed for heterogeneous panels. Considering a time effect in our analysis in order to meet the estimation assumption of cross-section independence, we find that the parameters of Int are correctly signed and statistically significant (Table 8), thereby providing further evidence of a long-run CIRP. However, note that given the fact that our estimates are well below the theoretical value of unity, our abovementioned results should be interpreted as evidence supporting the weak-form of the long-run CIRP.

5 Conclusion and Discussion

Using advanced nonstationary panel data estimation methods, we have examined the stationarity of forward premiums for advanced countries. Such methods introduce many types of heterogeneities and cross-sectional correlations in the tests. Furthermore, unlike previous studies, forward premiums with a wide variety of maturity length are analyzed in order to seek a conclusion more relevant to actual practices in forward markets.

In short, like previous research, we have confronted difficulties in drawing a clear conclusion about the stationarity of the forward premium, and discover that unusual historical events seem to have increased the level of nonstationarity in the premiums. However, unlike previous research on the Asian crisis, the impacts of the recent crises, notably the Lehman Shock, on the forward premiums are found to be more permanent, demonstrating its significant scale as a crisis. However interestingly, they do not have a persistent influence on the CIRP relationship. The sizable forward premium due to crises is found to be offset by interest rate differentials, leaving the CIRP as a valid long term concept. It follows that the

CIRP can be viewed as a long run equilibrium concept, particularly during tranquil times. Furthermore, unlike previous studies, our result in general is reported to be indifferent even though a different numeraire currency is used for the analysis.

Our result is also consistent with recent developments on financial bubble research. Notably, Phillips et al (2011) have proposed a statistical method which evaluates the right-hand distribution of the unit root test in order to identify the timeline of so-called explosive bubbles. Their statistical hypotheses are rather different from the conventional unit root tests, and are noteworthy stating; the null of the random walk ($\rho = 1$) and the alternative of the explosive case ($\rho > 1$). Against this background, one could consider analysis of a violation of the CIRP using the concept of explosive bubbles. But the final conclusion presented in this paper should still be valid since even though a forward premium may be explosive due to financial crises, our result implies that interest rate differentials dampen such extraordinary movements in the long run.

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Table 1. Description of Forward Premiums (Mean)

	1w	1m	2m	3m	6m	9m	1y
				Numeraire (US$)			
Australia	4.20E-04	1.87E-03	3.66E-03	5.45E-03	1.09E-02	1.62E-02	2.15E-02
Canada	2.23E-05	4.82E-05	7.47E-05	9.90E-05	1.86E-04	3.13E-04	4.60E-04
Czech	2.71E-05	7.01E-05	1.23E-04	1.57E-04	2.40E-04	2.24E-04	1.61E-04
Denmark	-5.54E-06	-9.22E-05	-1.74E-04	-2.46E-04	-5.28E-04	-9.04E-04	-1.44E-03
Euro	-5.18E-05	-2.82E-04	-5.50E-04	-8.29E-04	-1.67E-03	-2.62E-03	-3.71E-03
NZ	5.24E-04	2.35E-03	4.58E-03	6.80E-03	1.35E-02	2.01E-02	2.66E-02
UK	2.02E-04	8.58E-04	1.67E-03	2.47E-03	4.85E-03	7.10E-03	9.25E-03
HK	-8.20E-05	-3.50E-04	-6.57E-04	-9.19E-04	-1.48E-03	-1.76E-03	-1.85E-03
Japan	-5.65E-04	-2.53E-03	-4.98E-03	-7.45E-03	-1.49E-02	-2.26E-02	-3.05E-02
Norway	2.57E-04	1.10E-03	2.14E-03	3.16E-03	6.00E-03	8.64E-03	1.11E-02
Singapore	-2.66E-04	-1.18E-03	-2.34E-03	-3.53E-03	-7.03E-03	-1.04E-02	-1.39E-02
Sweden	-4.63E-05	-2.27E-04	-4.49E-04	-6.73E-04	-1.25E-03	-1.61E-03	-1.86E-03
Taiwan	-3.45E-04	-1.30E-03	-2.54E-03	-3.81E-03	-7.64E-03	-1.11E-02	-1.44E-02
Average	**6.98E-06**	**2.58E-05**	**4.29E-05**	**5.22E-05**	**9.06E-05**	**1.22E-04**	**1.09E-04**
				Numeraire (Euro)			
Australia	4.79E-04	2.16E-03	4.22E-03	6.29E-03	1.25E-02	1.89E-02	2.52E-02
Canada	7.98E-05	3.36E-04	6.31E-04	9.34E-04	1.86E-03	2.94E-03	4.17E-03
Czech	8.90E-05	3.63E-04	6.83E-04	9.96E-04	1.92E-03	2.85E-03	3.88E-03
Denmark	5.62E-05	2.00E-04	3.86E-04	5.92E-04	1.15E-03	1.72E-03	2.28E-03
NZ	5.84E-04	2.64E-03	5.14E-03	7.64E-03	1.52E-02	2.27E-02	3.03E-02
UK	2.43E-04	1.13E-03	2.21E-03	3.29E-03	6.51E-03	9.71E-03	1.30E-02
HK	-2.11E-05	-5.81E-05	-9.76E-05	-8.11E-05	2.02E-04	8.68E-04	1.87E-03
Japan	-5.02E-04	-2.24E-03	-4.42E-03	-6.61E-03	-1.33E-02	-2.00E-02	-2.68E-02
Norway	3.19E-04	1.40E-03	2.70E-03	4.00E-03	7.68E-03	1.13E-02	1.48E-02
Singapore	-2.08E-04	-8.88E-04	-1.78E-03	-2.69E-03	-5.36E-03	-7.81E-03	-1.02E-02
Sweden	1.50E-05	6.49E-05	1.11E-04	1.65E-04	4.34E-04	1.02E-03	1.86E-03
Taiwan	-2.83E-04	-1.01E-03	-1.97E-03	-2.98E-03	-5.96E-03	-8.47E-03	-1.07E-02
Average	**6.94E-05**	**3.37E-04**	**6.43E-04**	**9.51E-04**	**1.89E-03**	**2.95E-03**	**4.10E-03**

Note: Full sample (1999M1-2011M3). The US/Euro rate is not shown here since it is a reciprocal of the Euro/US rate. The contract maturities are one week (1w), one month (1m), two months (2m), three months (3m), six months (6m), nine months (9m) and one year (1y).

Table 2. Description of Forward Premiums (Standard Deviation)

	1w	1m	2m	3m	6m	9m	1y
				Numeraire (US$)			
Australia	3.35E-04	1.49E-03	2.88E-03	4.29E-03	8.60E-03	1.28E-02	1.69E-02
Canada	1.73E-04	7.47E-04	1.47E-03	2.20E-03	4.38E-03	6.48E-03	8.56E-03
Czech	3.27E-04	1.46E-03	2.80E-03	4.18E-03	8.01E-03	1.15E-02	1.47E-02
Denmark	3.02E-04	1.28E-03	2.42E-03	3.56E-03	6.83E-03	9.86E-03	1.27E-02
Euro	2.82E-04	1.24E-03	2.41E-03	3.58E-03	6.99E-03	1.02E-02	1.31E-02
NZ	3.45E-04	1.54E-03	2.95E-03	4.33E-03	8.38E-03	1.21E-02	1.57E-02
UK	2.35E-04	1.06E-03	2.05E-03	3.06E-03	6.04E-03	8.85E-03	1.14E-02
HK	4.93E-04	4.93E-04	9.49E-04	1.40E-03	2.95E-03	4.61E-03	6.40E-03
Japan	3.93E-04	1.72E-03	3.36E-03	5.01E-03	9.84E-03	1.45E-02	1.88E-02
Norway	4.16E-04	1.84E-03	3.58E-03	5.30E-03	1.03E-02	1.49E-02	1.91E-02
Singapore	2.63E-04	1.12E-03	2.11E-03	3.09E-03	5.86E-03	8.40E-03	1.09E-02
Sweden	3.55E-04	1.57E-03	3.05E-03	4.53E-03	8.79E-03	1.28E-02	1.64E-02
Taiwan	1.03E-03	2.84E-03	4.47E-03	6.19E-03	1.04E-02	1.35E-02	1.71E-02
Average	**3.81E-04**	**1.42E-03**	**2.65E-03**	**3.90E-03**	**7.49E-03**	**1.08E-02**	**1.40E-02**
				Numeraire (Euro)			
Australia	2.01E-04	8.84E-04	1.69E-03	2.52E-03	5.08E-03	7.59E-03	9.99E-03
Canada	1.68E-04	7.32E-04	1.45E-03	2.17E-03	4.37E-03	6.46E-03	8.42E-03
Czech	2.64E-04	1.16E-03	2.26E-03	3.36E-03	6.53E-03	9.67E-03	1.27E-02
Denmark	6.97E-05	2.75E-04	4.60E-04	6.93E-04	1.21E-03	1.68E-03	2.12E-03
NZ	2.45E-04	1.06E-03	1.99E-03	2.90E-03	5.46E-03	7.75E-03	9.79E-03
UK	1.85E-04	8.02E-04	1.56E-03	2.31E-03	4.55E-03	6.71E-03	8.74E-03
HK	3.06E-04	1.33E-03	2.61E-03	3.90E-03	7.85E-03	1.18E-02	1.56E-02
Japan	2.43E-04	1.05E-03	2.06E-03	3.05E-03	5.96E-03	8.75E-03	1.13E-02
Norway	2.74E-04	1.21E-03	2.31E-03	3.38E-03	6.40E-03	9.11E-03	1.15E-02
Singapore	2.38E-04	9.79E-04	1.87E-03	2.74E-03	5.24E-03	7.53E-03	9.73E-03
Sweden	1.18E-04	5.11E-04	9.79E-04	1.45E-03	2.87E-03	4.26E-03	5.55E-03
Taiwan	1.06E-03	3.07E-03	5.02E-03	7.07E-03	1.23E-02	1.66E-02	2.13E-02
Average	**2.81E-04**	**1.10E-03**	**2.05E-03**	**3.01E-03**	**5.75E-03**	**8.32E-03**	**1.08E-02**

Note: Full sample (1999M1-2011M3). The US/Euro rate is not shown here since it is the same as the Euro/US rate.

Table 3. Breusch-Pagan Test of Independence

	1w	1m	2m	3m	6m	9m	1y
				Numeraire (US$)			
χ^2 (78)	2319.042	3166.637	3410.989	3394.386	2674.150	2279.116	2196.319
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				Numeraire (Euro)			
χ^2 (78)	1318.854	1259.225	1289.248	1196.459	1165.527	974.371	931.446
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: Full sample. This test examines the null of cross-sectional independency of the data and is based on the seemingly unrelated regression estimators. The statistics are distributed as χ^2 with the degree of freedom equal to N*(N-1)/2 where N is the number of premiums.

Table 4. LM Panel Unit Root Tests With/Without Level Shifts

	1w	1m	2m	3m	6m	9m	1y
				Numeraire (US$)			
No shift	**-3.464**	-1.024	-0.871	-0.620	-1.005	-1.102	-0.896
One shift	**-14.967**	**-8.856**	**-7.132**	**-7.293**	**-6.603**	**-7.191**	**-7.602**
Two shifts	**-29.171**	**-11.485**	**-13.845**	**-13.058**	**-12.575**	**-11.814**	**-12.079**
				Numeraire (Euro)			
No shift	**-3.892**	-0.652	-0.534	-0.630	-1.341	-1.128	-0.934
One shift	**-14.141**	**-7.496**	**-6.659**	**-6.741**	**-6.793**	**-6.923**	**-7.406**
Two shifts	**-23.948**	**-16.555**	**-12.872**	**-12.527**	**-12.057**	**-11.549**	**-12.044**

Notes: The test is based on Im et al (2005) and the statistics follow the standard normal distribution. Boldfaced figures are statistics significant at the 5% level or higher.

Table 5. Unit Root Tests for Each Premium (With One Shift)

	1w	1m	2m	3m	6m	9m	1y
				Numeraire (US$)			
Australia	**-5.052**	-2.979	*-3.231*	*-3.457*	**-3.914**	**-4.239**	**-4.468**
Canada	**-6.373**	-3.118	-3.029	-2.964	*-3.34*	*-3.53*	*-3.515*
Czech	-2.467	-2.082	-2.639	-2.630	-2.195	-2.456	-2.553
Denmark	**-3.854**	**-4.131**	-3.125	-3.087	-2.73	-2.705	-2.638
Euro	**-6.196**	**-4.406**	*-3.489*	-3.15	-2.794	-3.088	-2.905
NZ	**-4.468**	*-3.327*	*-3.522*	**-3.777**	**-3.88**	**-3.773**	**-3.906**
UK	**-5.045**	-3.084	-2.518	-2.618	-2.255	-2.484	-2.763
HK	-2.828	-2.431	-2.328	-2.727	-2.510	-2.689	-2.845
Japan	*-3.288*	-2.316	-2.257	-2.261	-2.376	-2.282	-2.383
Norway	-2.066	-2.320	-1.653	-2.237	-2.182	-2.386	-2.476
Singapore	-2.881	-3.026	-2.765	-2.836	-3.071	-3.125	*-3.344*
Sweden	-3.156	-3.005	-2.965	-3.038	-2.685	-2.861	-2.884
Taiwan	**-9.564**	**-8.122**	**-7.057**	**-6.599**	**-5.528**	**-5.056**	**-4.844**
				Numeraire (Euro)			
Australia	**-5.149**	-3.049	*-3.401*	*-3.363*	**-4.011**	**-4.376**	**-4.686**
Canada	**-7.167**	*-3.283*	*-3.350*	-3.301	*-3.560*	**-3.776**	**-3.779**
Czech	**-4.361**	-2.006	-2.755	-2.695	-2.194	-2.359	-2.559
Denmark	*-3.410*	**-3.775**	-3.004	-2.802	-2.506	-2.608	-2.561
NZ	**-4.208**	*-3.405*	*-3.501*	**-3.715**	**-3.881**	**-3.774**	**-3.914**
UK	**-5.214**	-3.148	-2.718	-2.801	-2.869	-2.625	-2.703
HK	-3.025	-2.572	-2.454	-2.387	-2.586	-2.723	-2.889
Japan	-3.092	-2.143	-2.090	-2.063	-2.220	-2.215	-2.199
Norway	-1.970	-2.160	-1.735	-2.260	-2.196	-2.332	-2.417
Singapore	-3.082	-2.891	-2.796	-2.913	-3.117	-3.163	*-3.389*
Sweden	-2.891	-2.843	-2.832	-2.923	-2.890	-2.700	-2.733
Taiwan	**-9.562**	**-8.141**	**-7.123**	**-6.667**	**-5.616**	**-5.166**	**-4.949**

Notes: Tests are based on Lee and Strazicich (2004). The critical values for the 5 and 10% significance levels are -3.566 and -3.211. Boldfaced figures are statistics significant at the 5% level or higher, and italic figures are at the 10% significance level.

Table 6. Unit Root Tests for Each Premium (With Two Shifts)

	1w	1m	2m	3m	6m	9m	1y
				Numeraire (US$)			
Australia	**-8.140**	-3.501	**-3.941**	**-3.855**	**-4.449**	**-4.709**	**-5.012**
Canada	**-7.296**	*-3.352*	*-3.722*	*-3.60*	**-3.884**	**-3.974**	**-3.849**
Czech	**-4.395**	-3.044	*-3.780*	*-3.720*	*-3.564*	*-3.758*	*-3.629*
Denmark	**-8.622**	-2.946	**-4.642**	**-4.123**	**-4.054**	*-3.645*	*-3.523*
Euro	**-11.022**	-2.742	**-4.673**	**-4.033**	**-4.039**	*-3.556*	-3.35
NZ	**-5.620**	**-4.236**	**-4.690**	**-5.038**	**-4.928**	**-4.647**	**-4.722**
UK	**-8.860**	-3.224	**-4.742**	**-4.728**	**-4.258**	*-3.784*	*-3.838*
HK	**-3.877**	**-5.542**	*-3.805*	-3.491	*-3.655*	*-3.525*	*-3.606*
Japan	**-5.902**	-2.778	-3.502	*-3.547*	-3.496	-3.422	**-4.054**
Norway	-2.679	-2.796	-2.472	-2.581	-2.686	-3.014	-3.223
Singapore	**-6.809**	**-4.355**	*-3.767*	*-3.695*	*-3.725*	*-3.700*	**-3.854**
Sweden	**-4.034**	-3.059	*-3.573*	*-3.607*	-3.359	-3.259	-3.213
Taiwan	**-10.098**	**-8.290**	**-7.535**	**-7.072**	**-5.961**	**-5.446**	**-5.104**
				Numeraire (Euro)			
Australia	**-8.673**	**-3.968**	**-3.969**	**-3.949**	**-4.487**	**-4.761**	**-5.122**
Canada	**-7.919**	**-4.877**	**-3.847**	*-3.784*	**-4.019**	**-4.111**	**-4.035**
Czech	**-4.491**	*-3.678*	-3.404	*-3.504*	-3.280	-3.464	*-3.538*
Denmark	**-6.255**	**-5.302**	**-4.230**	*-3.708*	*-3.621*	*-3.381*	-3.266
NZ	**-5.388**	**-4.826**	**-4.843**	**-5.010**	**-4.933**	**-4.692**	**-4.774**
UK	**-6.468**	**-4.908**	**-4.761**	**-4.732**	**-4.124**	**-3.906**	**-3.978**
HK	**-4.137**	**-4.706**	**-3.982**	*-3.612*	*-3.790*	*-3.653*	*-3.725*
Japan	**-5.192**	-3.403	-3.214	-3.391	-3.223	-3.221	*-3.733*
Norway	-2.548	-3.072	-2.309	-2.601	-2.766	-2.912	-3.102
Singapore	**-7.454**	**-5.896**	**-4.194**	**-4.227**	**-4.147**	**-3.990**	**-4.008**
Sweden	*-3.743*	*-3.563*	*-3.508*	*-3.598*	-3.476	-3.190	-3.288
Taiwan	**-10.139**	**-8.494**	**-7.509**	**-7.043**	**-5.959**	**-5.466**	**-5.257**
US	**-3.858**	**-3.904**	-2.994	-2.770	-3.111	-3.103	-3.077

Notes: Tests are based on Lee and Strazicich (2004). The critical values for the 5 and 10% significance levels are -3.842 and -3.504. Boldfaced figures are statistics significant at the 5% level or higher, and italic figures are at the 10% significance level.

Table 7. Shift-Dates of World Key Economic Data

Data	Andrews-Quandt	Andrews-Ploberger	Estimated Shift Date
Housing price	173.836 [0.000]	83.105 [0.000]	2006M5
Commodity price	5.678 [0.166]	0.887 [0.246]	2008M6
Federal fund rate	101.760 [0.000]	47.851 [0.000]	2008M8

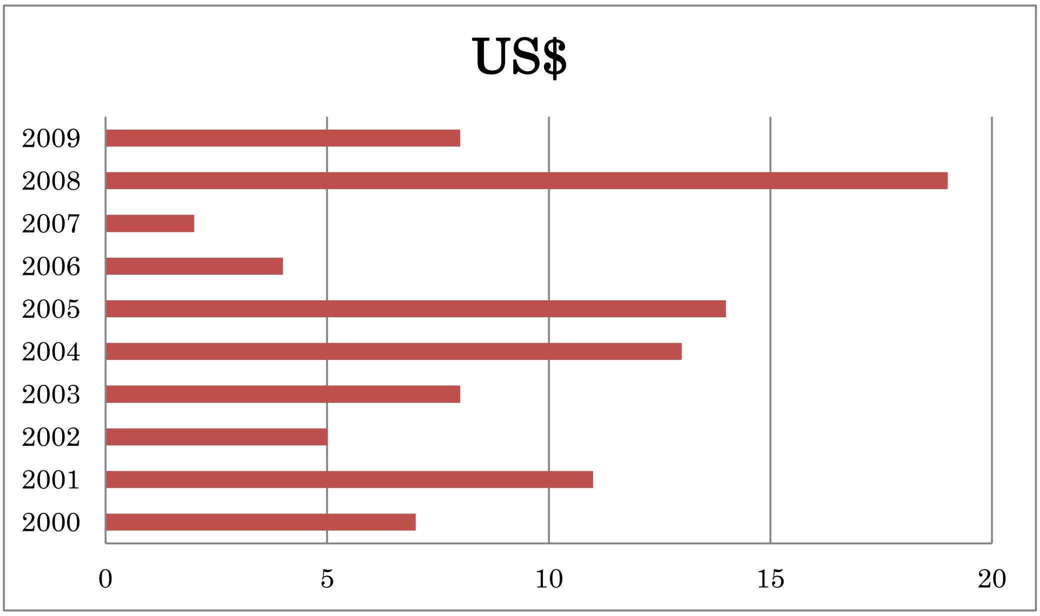
Note: Full sample. P-values are reported in brackets and are obtained via the bootstrap method with 10,000 replications.

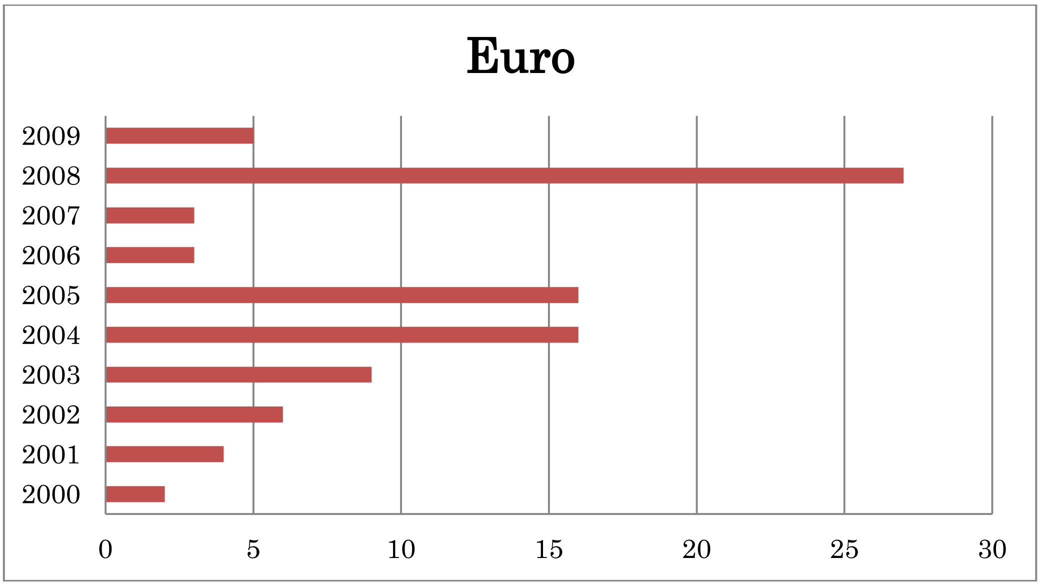
Table 8. The Covered Interest Rate Parity Condition

		1w	1m	2m	3m	6m	9m	1y
DOLS estimates					Numeraire (US$)			
Int		0.021	0.087	0.171	0.255	0.504	0.745	0.980
	P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Int_us		-0.022	-0.081	-0.158	-0.235	-0.462	-0.683	-0.894
	P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Panel cointegration test								
P_α		-26.274	-21.656	-14.714	-13.035	-8.928	-6.809	-6.025
	P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DOLS estimates					Numeraire (Euro)			
Int		0.020	0.087	0.170	0.254	0.501	0.740	0.974
	P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Int_euro		-0.018	-0.081	-0.158	-0.235	-0.461	-0.677	-0.886
	P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Panel cointegration test								
P_α		-17.046	-11.302	-9.282	-7.986	-5.900	-4.597	-3.710
	P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: Tests are based on Westerlund (2007) and p-values on the bootstrap method (10,000 replications). The Dynamic OLS (Kao and Chiang, 2000) with 6 lags and leads is used to estimate parameters for interest rates. “Int” contains interest rates of home countries, and “Int_us” and “Int_euro” are interest rates of the US and the Euro area respectively.

Figure 1. Frequency of Shift Dates





Notes: Based on one shift in each premium.