Strong Sterling Pound and Weak European Currencies in the Crises: Evidence from Covered Interest Parity of Secured Rates [*]

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Abstract

In the post Lehman period, the interest rate of the US dollar became low on the forward contract because of its role as international currency. However, in the Euro crisis, that of the Sterling pound became equally low, while the other European currencies increased its liquidity premium. By using secured rates, the following analysis examines why the Sterling pound and the Danish kroner showed asymmetric features in the two crises. The regression results suggest that there was a structural break in the determinants of deviations from covered interest parity (CIP) condition across the European currencies during the crises. Currency-specific money market risk was critical in explaining the deviations in the GFC, while EU banks' credit risk were useful in explaining the deviations in the Euro crisis. The asymmetry explains different features between the Sterling pound and the Danish kroner in the two crises.

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1. Introduction

The global financial crisis (GFC) and the following Euro crisis had enormous impacts on international markets. In particular, covered interest parity (CIP) condition, which was solidly anchored in riskless arbitrage during tranquil periods, was violated substantially during the crises. Even using secured rates such as overnight index swap (OIS) rates, the violation was substantial in the crises. In particular, when comparing interest rates across currencies, the CIP condition suggests that the US dollar had lower interest rate than any other currency in the crisis. Money that provides with liquidity has lower interest rate than any other safe asset. In the global crises, the role of the US dollar as international liquidity similarly made its interest rate lower than those of the other major currencies on the forward market.

However, when comparing interest rates across the other currencies, we can see that the Sterling pound had smaller deviations than the other major currencies after the early 2009. In particular, since the second half of 2010, the Sterling pound came to have equally low interest rate as the US dollar on the forward contract. In contrast, the other European currencies had higher interest rates in the Euro crisis. Figure 1 depicts daily CIP deviations of the Euro from three European currencies from June 1, 2008 to February 15, 2012. For currency k (k = the Sterling pound, the Swiss franc, and the Danish kroner), we calculated deviations of the CIP conditions by the annualized value of $(1+ i^{k}_{t}) - (1+i^{euro}_{t})(f^{k}_{t+1}/e^{k}_{t})$, where i^{k}_{t} is three-month currency k's OIS rate, i_{t}^{euro} is three-month Euro OIS rate, e^{k}_{t} is the Euro spot exchange rate against currency k, and f^{k}_{t+1} is its three-month forward exchange rate. All of the data the unit of which is basis point are downloaded from Datastream. Even when we use the Euro as the benchmark currency, we can see significant positive deviations in the Swiss franc and the Danish kroner in the figure. The upward deviations which became largest after the Lehman shock still persisted in the Euro crisis. In contrast, the Sterling pound showed negative deviations throughout the period. In particular, the downward deviations were widened in the second half of 2011 when the Euro crisis became more serious. The results imply that in the Euro crisis, the Euro remained chosen as a regional liquidity among non-Euro members in Europe but that the

Sterling pound was preferred more than the Euro in the international money markets.

The purpose of this paper is to explore what made the CIP deviations from the Euro so different between the Sterling pound and the Danish kroner in the twin crises. The role of the Euro as a regional liquidity in Europe might explain why the Euro's interest rate was lower than those of the Danish kroner and the Swiss franc in the crises. In contrast, the lower interest rate of the Sterling pound may be attributable not only to UK's less reliance on the Euro but also to the role of London market as a money center. In the foreign exchange transactions, London is the largest money center in the world. Based on BIS's Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity, Table 1 summarizes currency shares of geographical distribution of global foreign exchange market turnover in 1998, 2001, 2004, 2007, 2010, and 2013. It indicates that the UK share has been twice as large as the US share and has been much larger than the other shares. In particular, the UK share exceeded 40% in 2013. No other European countries had comparable shares to the UK. This implies that the transactions are highly thick in the London market, which might have made the Sterling pound useful in international money markets.

In the following analysis, our regression results suggest that there was a structural break in the determinants of the deviations in the two crises. In the GFC, currency-specific money market risk had a similar effect on the deviations of the Sterling pound and the Danish krone. In contrast, EU banks' credit risk had an asymmetric effect on the deviations of the two currencies in the Euro crisis. In Europe, it was in early 2010 when fears of a sovereign debt crisis developed among investors concerning Greece's ability to meet its debt obligations. This led to a crisis of confidence, indicated by a widening of bond yield spreads and the cost of risk insurance on credit default swaps. Under the turbulence in Europe, there are asymmetric responses between the Sterling pound and the Danish krone. Our empirical results suggest that even though the Danish economy had relatively sound fundamentals, its currency faced Euro's liquidity risk in the crisis.[1] In contrast, investors increased

[1] In July 2012, Danish central bank adopted a special monetary policy to set some of its policy rate below zero. But our sample does not include this special period.

their liquidity preference for the Sterling pound in the Euro crisis because the London market was more liquid in the foreign exchange transactions

In previous literature, several studies have explored sources of deviations from CIP condition in the global financial crisis. Baba and Packer (2009a,b) find that deviations from covered interest parity were negatively associated with the creditworthiness of European and US financial institutions. The authors such as Fong, Valente, and Fung (2010) and Coffey, Hrung, and Sarkar (2009) show that in addition to credit risk, liquidity and market risk played important roles in explaining the deviations. Grioli and Ranaldo (2010) find that the results were essentially the same even if we used secured rates such as OIS. Fukuda (2012) finds that in the GFC, the Tokyo market had larger deviations than the London and the New York markets even though Japanese banks were more sound and healthy than EU and US banks. The following analysis confirms some of the findings in previous studies, especially those based on secured rates. However, unlike previous studies, this analysis pays a special attention to different features across several European currencies before and after the Euro crisis which has not been discussed extensively in literature.

One important implication of this paper is that the degree of liquidity risk is not necessarily related with economic fundamentals such as banking sector's soundness. Denmark and Switzerland are European countries that had relatively sound economic fundamentals in the Euro crisis. However, due to strong linkages to the Euro, they suffered from Euro's liquidity shortage in the Euro crisis. In contrast, due to the fact that London is the largest money center in the world, UK did not suffer from liquidity shortage in the Euro crisis. The result is consistent with that of Fukuda (2011) who showed that in the GFC, the Tokyo market had higher liquidity risk than the London and the New York markets because the Tokyo market is less thick than the other two markets. In literature, several studies discussed money market risk in Europe in the GFC and in the Euro crisis (see, among others, Moessner and Allen (2013)). In particular, authors such as Mindested and Risbjerg (2011) and Risbjerg and Sangill (2012) discussed the Danish money market and its liquidity in the crisis period. Our empirical results will provide with supplementary explanations for determinants of money market

risk in Europe based on information obtained from CIP conditions between the Euro and other European currencies.

The rest of the paper is organized as follows. Section 2 presents a basic framework of our econometric tests. After explaining how to measure counter-party credit risk and liquidity risk in Section 3, Section 4 reports the results of our regressions. Section 5 investigates their robustness allowing alternative structural breaks. Section 6 concludes and refers to the implications.

2. Empirical Specification

The purpose of the following sections is to examine why several European currencies showed asymmetric deviations from the CIP conditions in the GFC and in the Euro crisis. Since our main interest is to compare the difference between the Euro and the other European currencies, the following analysis focuses the determinants of the CIP deviations between the Euro and the two European currencies: the Sterling pound and the Danish kroner. We chose the two currencies because UK is the country that has the largest money center in the world, while Denmark is an European country that relies heavily on Euro in the ERM II. They are also exceptional non-Euro members where relevant time-series data, especially OIS rate, is available for a long period.

The total sample period is from January 2, 2008 to February 15, 2012. Until section 4, we split the sample before and after January 1, 2010 to allow a structural break before and after the Euro crisis. There is no definitive consensus on when the GFC ended and when the Euro crisis started. But the market turbulences after the financial crisis of 2007–2008, known as the Global Financial Crisis (GFC), were almost stabilized in late 2009. In contrast, in October 2009, the Greek government admitted that it had misreported its official economic statistics for many years. Fears of a sovereign debt crisis then developed among investors concerning Greece's ability to meet its debt obligations. In the first few weeks of 2010, there was renewed anxiety about excessive national debt, with lenders demanding ever higher interest rates from several countries with higher debt levels, deficits and current account deficits. Splitting the sample before and after January 1, 2010 would be

approximately appropriate for the structural break. In section 5, we will show that alternative sample splits will not change the essential results in the paper.

Defining deviations from the CIP condition between the Euro and currency j (j = the Sterling pound and the Danish kroner) in period t by $Dev_t(j)$, the following analysis examines what factors explain $Dev_t(j)$ in the GFC and in the Euro crisis. By using daily data for the two sub-samples, we estimate the following equation:

$$(1) \quad Dev_t(j) = constant\ term + \sum_h \alpha_h \cdot Credit_t(h) + \sum_q \beta_q \cdot Credit_t(q) + \sum_k \gamma_k \cdot Liquidity_t(k) + \delta \cdot Market_t,$$

for j = the Sterling pound and the Danish kroner.

We calculate the dependent variable by $Dev_t(j) \equiv (1+i^j{}_t) - (1+i^{euro}{}_t)(f^j{}_{t+1}/e^j{}_t)$, where $i^j{}_t$ is three-month currency j's OIS rate, $i^{euro}{}_t$ is three-month euro OIS rate, $e^j{}_t$ is the Euro spot exchange rate against currency j, and $f^j{}_{t+1}$ is its three-month forward exchange rate. The OIS rates are secured rates that measure market participants' expected average policy rate over the relevant term. $Dev_t(j)$ thus reflects secured arbitrage that removes many of the counter-party credit risks. The unit is basis point. The spot exchange rates and three-month forward exchange rates used in the analysis are their interbank middle rates at 4pm in London time. The data are downloaded from Datastream.

The right hand side of (1) includes four types of risk measures in addition to the constant term. The first is $Credit_t(h)$ which is a credit risk measure in currency h (h = the US dollar, the Euro, the Sterling pound, and the Danish kroner) in period t. In the crises, term premiums in the international money market became heterogeneous across currencies. In particular, due to the role of the US dollar as international liquidity, traders were especially sensitive to a liquidity shortage of the US dollar in international transactions. The first type of measure is included in (1) to capture such currency-specific risk. We explore whether local currency risk and global currency risk had different impacts in the two subsample periods.

The second is $Credit_t(q)$ which is a credit risk measure in country q (q = the United States,

UK, EU, Ireland, and Denmark) in period *t*. In the GFC, the credit quality of European, UK, and US banks deteriorated substantially. In contract, in the Euro crisis, soared sovereign risk hit mainly European banks. This suggests that credit risk had country-specific features in the two crises which may be captured by $Credit_t(q)$. We explore whether different country risk had different impacts in the two subsample periods.

The third is $Liquidity_t(k)$ which is a liquidity risk measure in currency *k* against the US dollar (*k* = the Euro, the Sterling pound, Swiss franc, and the Danish kroner) in period *t*. In the financial turmoil, some traders are not given as much "balance sheet" to invest, which is perceived as a shortage of liquidity to them. Under this situation, the traders are reluctant to expose their funds during a period of time where the funds might be needed to cover their own shortfalls. Consequently, in the crisis, foreign exchange markets come under stress, and bid-ask spreads may be widened in the markets. The third type of measure is to capture such liquidity tightness in each currency.

The fourth is $Market_t$ which is a market risk measure in period *t*. For the measure, we use the Chicago Board Options Exchange Volatility Index (VIX) which is a popular measure of the implied volatility of S&P 500 index options. A high value corresponds to a more volatile market and therefore, more costly options. Often referred to as the fear index, the VIX represents a measure of the market's expectation of volatility over the next 30-day period. We explore whether global market risk had different impacts in the two subsample periods.

3. Basic Statistics of Various Risk Measures

3.1. Currency-specific credit risk

To measure the currency-specific credit risk $Credit_t(h)$, the following analysis uses the spreads between LIBOR and OIS rate in currency *h* (*h* = the US dollar, the Euro, the Sterling pound, and the Danish kroner). LIBOR (London Interbank Offered Rate) is a daily reference rate in the London interbank market calculated for various currencies, while OIS rate is a daily secured rate that removes counter-party credit risks. Since LIBOR is based on the interest rates at which banks borrow

unsecured funds from other banks in each currency, each spread reflects a counterparty credit risk in currency *h*.[2] For example, the US dollar-denominated LIBOR–OIS spread reflects credit risk of the US dollar, while the Euro-denominated LIBOR–OIS spread reflects that of the Euro. In calculating the spreads, we use daily data of three-month LIBORs which were published by the British Bankers' Association, after 11:00 a.m. each day (Greenwich Mean Time). And that of OIS rates which were downloaded from Datastream.[3]

Table 2 summarizes basic test statistics of these daily credit risk measures for the two sub-sample periods: from January 2, 2008 to December 31, 2009 and from January 2, 2010 to February 15, 2012. For comparison, it also reports basic test statistics of the same risk measures in the Swiss franc and the Japanese yen. All spreads had larger mean, median, standard deviation, and skewness for the first sub-sample period than for the second sub-sample period. Regardless of the currency denomination, the turbulence in the short-term money markets was more serious in the GFC than in the Euro crisis. But the contrast was especially conspicuous in the US dollar and the Sterling pound. The mean of the spreads in the US dollar which was close to 80 basis points for the first sub-sample dropped to about 20 basis points for the second sub-sample period. The mean in the Sterling pound which exceeded 90 basis points for the first sub-sample dropped to less than 30 basis points for the second sub-sample period. The sharply increased money market credit risk in the two currencies was relatively stabilized in the Euro crisis.

The mean of the Euro-denominated spreads also dropped significantly for the second sub-sample period. However, the spreads of the Euro, which were smaller than those of the US dollar and the Sterling pound for the first sub-sample, became larger for the second sub-sample. The Euro which was a relatively safe currency in the GFC became a relatively risky currency in the Euro crisis.

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[2] Taylor and Williams, (2009) use the same spreads in measuring credit risk. The spreads may have measurement errors because some panel banks acted strategically when quoting rates to the LIBOR survey during the global financial crisis (see, for example, Mollenkamp and Whitehouse [2008]). When the measurement errors exist, the estimated coefficient will be less significant in the first sub-sample period.

[3] The daily OIS rates are quoted in different time zones depending on their currency denomination. But since their daily changes are very small, it is unlikely that the time difference affect the spreads.

Among the European currencies, the Swiss franc had the smallest spread for both of the two sub-sample periods. This was partly because the data of the Swiss franc denominated spreads is available only after November 17, 2008. But on the whole, the Swiss franc was less risky currency in the money markets during the two crises. In contrast, the Danish kroner's spread remained high throughout the two sub-sample periods. The Danish kroner suffered from increased risk premium in the money markets during the two crises.

3.2. Country-specific credit risk

To measure the country-specific credit risk $Credit_t(q)$, the following analysis uses the credit default swap (CDS) prices for country q at 4pm in London time.. Since credit risk was conspicuous in banking sector, we use the daily time series of the five-year banks sector CDS indexes for EU, the United Kingdom, and the United States. To capture sovereign credit risk, we also use the daily time series of the five-year sovereign CDS for Ireland, Italy, and Denmark. The data is downloaded from Datastream, which is based on CMA Data Vision.

Table 3 summarizes basic test statistics for these daily banks sector and sovereign CDS for the two sub-sample periods (from January 2, 2008 to December 30, 2009 and from January 2, 2010 to February 15, 2012). For comparison, it also reports the same test statistics for sovereign CDS of US, Germany, France, Spain, and the United Kingdom. Among the three banks sector CDS indexes, US banks had larger mean, median, standard deviation, and skewness for the first sub-sample period. Although the Lehman shock damaged both European and UK banks, the credit quality US banks deteriorated most in the GFC. In contrast, European banks had larger mean, median, standard deviation, and skewness for the second sub-sample period. The mean, median, and standard deviation for EU banks sector in the second sub-sample period were more than doubled from those in the first sub-sample period and far exceeded those of US and UK banks in the same period. In the Euro crisis, the credit quality of European banks deteriorated dramatically.

Except for Ireland, sovereign CDS indexes were relatively stable for the first sub-sample

period. However, reflecting their fiscal crisis, the mean, median, standard deviation of sovereign CDS indexes for Italy, Spain, and Ireland increased dramatically in the second sub-sample period. French sovereign CDS index also increased its mean, median, standard deviation substantially in the Euro crisis. In contrast, CDS indexes for the UK and Denmark increased their mean and median only modestly and reduced their standard deviation in the same period. The mean and median of Germany CDS index was lowest not only in the first sub-sample period but also in the second sub-sample period. The Euro crisis had only limited impact on the UK and Danish sovereign risk and little on Germany sovereign risk.

3.3. Currency-specific liquidity risk

To measure the currency-specific liquidity risk $Liquidity_t(k)$, we use bid-ask spreads of three-month forward rates at 4pm in London time. We use the daily time series of the spreads for the Euro-dollar rate, the Sterling pound-dollar rate, and the Danish kroner-dollar rate. The bid-ask spreads are negligible in normal time. But when the market faces a shortage of liquidity, they tend to be widened in the forward markets. In particular, they increased sharply after the Lehman shock.

Table 4 summarizes basic statistics for these daily series for the two sub-sample periods (from January 2, 2008 to December 30, 2009 and from January 2, 2010 to February 15, 2012). For comparison, it also reports the corresponding statistics of the spreads for the Swiss franc-dollar rate and the Japanese yen-dollar rate. Because of the Lehman shock, the bid-ask spreads had larger mean and standard deviation in the first sub-sample period than in the second sub-sample period. But when excluding September and October in 2008 in the first sub-sample period, the basic statistics of the bid-ask spreads were not so different between the two sub-sample periods.

In both sub-periods, the Euro-dollar spreads had the smallest mean, median, and maximum. This suggests that the Euro is an international currency with the smallest transaction costs when turning over from or to the US-dollar. In both periods, the Sterling pound-dollar spreads had the second smallest mean, median, and maximum. Reflecting limited turnovers in the foreign exchange

markets, it had larger mean and median than the Euro-dollar spreads in the first-subsample period. However, the difference in mean and median became negligible in the second sub-sample period when Euro member countries faced further turmoil. In particular, the Sterling pound-dollar spreads had smaller standard deviation than the Euro-dollar spreads in the second sub-sample period.

In contrast, the Swiss franc-dollar spreads had the largest mean, median, and maximum in both sub-periods. Unlike the other European countries, the Euro crisis had limited impacts on the Swiss franc risk premium. In addition, the Swiss franc appreciated not against Euro but against the US dollar especially before the Swiss National Bank's unlimited interventions in September 2011. Regardless of these symptoms, the Swiss franc had high transaction costs when turning over from or to the US-dollar in the forward market. The spreads were larger not only than the Euro and the Sterling pound but than Japanese yen and the Danish kroner.

4. Estimation Results

This section reports our empirical results concerning the effects of various risk measures on the CIP deviations of the Sterling pound and the Danish kroner from the Euro. In each regression we use daily data for each of the two sub-sample periods: from January 2, 2008 to December 30, 2009 and from January 2, 2010 to February 15, 2012. The unit of each interest rate is basis point. We run OLS regressions for equation (1) with two lagged dependent variables. To be synchronized with the dependent variable, the country-specific credit risk $Credit_t(q)$ and the currency-specific liquidity risk $Liquidity_t(k)$ are the values at 4pm in London time. But the other explanatory variables are the latest values before 4pm in London time. The standard errors of the coefficients are calculated by Newey-West HAC Standard Errors & Covariance with lag truncation 6. The estimated results with and without currency-specific liquidity risks are summarized in Table 5. It shows that several credit and liquidity risk measures had significant effects on the CIP deviations of the Sterling pound and those of the Danish kroner. However, many of the risk measures had different significance levels and different signs for the two sub-sample periods, suggesting structural breaks before and after the Euro

crisis. We also found some asymmetry between the Sterling pound and the Danish kroner.

4.1. Currency-specific credit risk

Regarding currency-specific credit risk measures, most of them had significant impact only in the first sub-sample period. In the first sub-sample period, the Euro-denominated spread (i.e., LIBOR–OIS spread) had a significantly positive effect on the deviations both in the Sterling pound and in the Danish kroner. The pound-denominated spread had a significantly negative effect on the Sterling pound's deviations, and so did the kroner-denominated spread on the Danish kroner's deviations. The symmetric results indicate that in the GFC, an increase in currency-specific credit risk made the currency's liquidity tighter and decreased its secured interest rate on the forward contract. In addition, the US dollar-denominated spread had a significantly negative effect for the Sterling pound's deviations. Global liquidity shortage after the Lehman shock made not only the US dollar interest rate but also the Sterling pound interest rate lower on the forward contract, suggesting that the Sterling pound was a substitute for the US dollar in the international money markets.

In contrast, in the second sub-sample period, the Euro-denominated spreads were significant neither in the Sterling pound nor in the Danish kroner. This implies that a rise of Euro-specific risk premium had little impact on the relative interest rate between the Euro and the other European currencies. Unlike in the GFC, markets became less sensitive to a liquidity shortage of the Euro in the Euro crisis. In case of the spread denominated in local currency, it still had a significantly negative effect both on the Sterling pound's deviations and on the Danish kroner's deviations. But its coefficient is much smaller and less significant than that in the first sub-sample period. This may reflect the fact that coordinated monetary policies by central banks were successful in reducing liquidity risk in the international money markets in the second sub-sample period. Unlike in the GFC, the US dollar-specific spread had a significantly positive effect on the Sterling pound's deviations. This implies that a decline of the US dollar-specific risk premium increased demand for the Sterling pound in the Euro crisis, suggesting a complementarity between the US dollar and the Sterling pound

in the Euro crisis.

4.2. Country-specific credit risk

Regarding the currency-specific measures, almost all of the banks sector CDS had an insignificant effect in the first sub-sample period. The Lehman shock damaged the credit quality of both the US and European banks. As a result, country-specific banks sector CDS increased in the GFC. The increased risk might have changed the relative interest rate between the US dollar and European currencies. However, it did not lead to a significant change in the relative interest rate between the Euro and the other European currencies. In the Danish kroner, sovereign risk in Ireland had a significantly positive coefficient. This may reflect some vulnerability of the Danish kroner to the crisis. However, it had no significant impact on the Sterling pound's deviations. The results may reflect the fact that country-specific credit risk had been relatively stable in Europe except for Ireland until the end of 2009. They may also suggest that the GFC was a liquidity crisis where sovereign risk was less important than money market risk on the forward contract.

In contrast, EU banks sector CDS had a significant effect on the deviations of both the Sterling pound and the Danish kroner in the second sub-sample period. It is noteworthy that the coefficient of EU banks sector CDS had opposite signs between the Sterling pound and the Danish kroner. In the case of the Sterling pound, a rise of European banking crisis increased precautionary demand for the Sterling pound and decreased Pound's secured interest rate. This may reflect the fact that the Sterling pound substituted the role of the Euro as an international currency in the crisis. In contrast, in the case of Danish kroner, a rise of European banking crisis increased precautionary demand for the Euro and increased Kroner's secured interest rate. For Danish international transactions, the Euro is an important counterpart currency in the turnovers. In the Euro crisis, it thus became more indispensable to avoid Euro's shortage for Denmark, which decreased the secured interest of the Euro on the Danish forward contracts.

In the second sub-sample period, Irish CDS had a significant effect on the Sterling pound's

deviations and so did Danish CDS on the Danish kroner's deviations. From late 2009, fears of a European sovereign debt crisis developed among investors as a result of the rising government debt levels around the world together with a wave of downgrading of government debt in some European states. Concerns intensified in early 2010, particularly in April 2010 when downgrading of Greek government debt to junk bond status created alarm in financial markets. The significant coefficients of the sovereign CDS reflected the environments. Due to a strong linkage between Ireland, a rise of Irish sovereign risk decreased precautionary demand for the Sterling pound and increased the Pound's secured interest rate. In contrast, a rise of Danish sovereign risk decreased precautionary demand for the Euro and decreased the Krone's secured interest rate.

4.3. Currency-specific liquidity risk

Regarding the effects of currency-specific liquidity risks in the first subsample period, none of them was significant in the Sterling pound. In contrast, the coefficient of bid-ask spreads for the kroner-dollar rate was significantly positive, while that for the Euro-dollar rate was significantly negative in the Danish kroner. Unlike in the global transactions, turnover costs from or to the Euro are vital in the regional transactions in Europe. Consequently, in Denmark, increased bid-ask spreads for the Euro increase precautionary demand for the Euro and decrease the Euro's secured interest rate, while increased bid-ask spreads for the Kroner decrease precautionary demand for the Euro and increase the Euro's secured interest rate.

In the second sub-sample period, the coefficient of the pound-dollar spreads was significantly negative in the Sterling pound. The tighter liquidity in the Sterling pound increases precautionary demand for the Sterling pound and decreases pound's secured interest rate. This probably reflects the fact that demand for the Sterling pound was determined from global perspectives rather than from regional perspectives in the Euro crisis. In contrast, in the Danish kroner, no coefficient of bid-ask spread was significant. In the Euro crisis, increased regional credit risk was more vital than a shortage liquidity for the Danish international transactions. Consequently, even if

turnover costs from or to the US dollar increased, it affected Danish precautionary demand little and led its secured interest rate relatively unchanged against the Euro secured rate.

4.4. Market risk

In the first sub-sample period, the estimated coefficient of VIX was significant neither in the Sterling pound nor in the Danish kroner. This suggests that the market risk did not play a critical role in the GFC. In contrast, in the second sub-sample period, the estimated coefficient of VIX was significantly negative in the Sterling pound and was significantly positive in the Danish kroner. A rise of VIX made the Pound's secured rate lower than the Euro's secured rate but made the Danish secured interest rate higher. The increased market risk in the Euro crisis shifted demand of international transactions from the Euro to the Sterling pound, while it increased precautionary demand for the Euro in regional countries such as in Denmark. Recall that similar asymmetric effects were observed for the coefficients of EU banks sector CDS. As the market risk increased in the Euro crisis, the Sterling pound substituted the role of the Euro as an international currency, while precautionary demand for the Euro increased in Denmark and increased the Kroner's secured interest rate.

5. Robustness test

Until the last section, we have examined what determined the CIP deviations before and after the beginning of January 2012. The separate estimation results for the two sub-sample periods showed substantial structural changes in the coefficients. For example, the Chow Breakpoint test F-statistics is 6.65 for the Sterling pound and 12.25 for the Danish kroner, both of which reject the hypothesis that there is no structural break at 1% significance level. However, since there is no consensus on when the GFC ended and when the Euro crisis began, the choice of the sub-samples was arbitrary.

The purpose of this section is to explore how the use of alternative subsample periods may change the essential results in the last section. In the analysis, we apply the Bai-Perron test which

extended the Quandt-Andrews test by allowing for multiple unknown breakpoints.[4] Assuming 15% trimming and allowing error distributions to differ across breaks, we use the Bai-Perron test to explore multiple unknown break dates and their significance in our sample. As summarized in Table 6, scaled F-statistic detected four structural break dates in the Sterling pound and three structural break dates in the Danish kroner. In case of sequentially determined breaks, they were October 22, 2008, June 4, 2009, August 27, 2010, and July 6, 2011 in the Sterling pound, while they were January 6, 2009, December 29, 2009, and December 28, 2010 in the Danish kroner. The detected structural break dates are not only frequent but also do not coincide with economic events during the crises. But based on the detected dates, we suppose that the GFC period is from January 2, 2008 to June 4, 2009 for the Sterling pound and from January 2, 2008 to January 6, 2009 for the Danish kroner.[5] We also suppose that the Euro crisis period is from August 27, 2010 to July 6, 2011 for the Sterling pound and from December 29, 2009 to December 28, 2010 for the Danish kroner.

Except for the sample periods, the estimation method is the same as that in the last section. Table 7 reports the estimation results with currency-specific liquidity risks for the new sub-samples. Even though both of the sub-sample periods are substantially shortened, the estimation results are essentially the same as those in the last section. That is, most of the currency-specific credit risk measures are statistically significant only in the first sub-sample, while EU banks' credit risk measures are statistically significant only in the second sub-sample.

In the first sub-sample, the coefficients of Euro-specific and local currency-specific credit risk measures remained statistically significant and having the same sign with those in the last section. This is consistent with our view that money market risk explains the CIP deviations in the GFC. In contrast, in the second sub-sample, the coefficient of the pound-denominated spread became insignificant in the Sterling pound, while the coefficients of Euro-specific and local currency-specific credit risk measures became significant in the Danish krone. Money market risk may remain

[4] Bai and Perron (2003) provided theoretical and computational results.
[5] To avoid short samples, we neglected the break date October 22, 2008 that occurred in the midst of the GFC.

important in explaining the CIP deviations of the Krone even in the Euro crisis.

Regarding the currency-specific measures, the coefficient of EU banks' credit risk became insignificant in the Danish krone in the first sub-sample period. However, it remained significant and having the same sign in the second sub-sample period, supporting our view that a rise of European banking crisis had opposite effects on the Sterling pound and on the Danish kroner in the Euro crisis. Compared with those in Table 5, sovereign risks had a tendency to reduce their impacts in Table 7. In particular, the effect of Irish CDS became insignificant in the Danish kroner in the first sub-sample and in the Sterling pound in the second sub-sample, while it became significant in the Danish kroner in the second sub-sample. Because of their dramatic changes, the effects of sovereign risks may be less robust for the choice of the sub-sample periods.

The effects of currency-specific liquidity risk and market risk are very similar with those in Table 5. But the effect of the market risk became statistically significant in the Danish krone in the first sub-sample period and in the Sterling pound in the second sub-sample in Table 7.

6. Concluding Remarks

Financial crises increase various premiums in national and regional financial markets. But unlike medium- or long-term financial markets, liquidity shortage became vital in financial turmoil. In the post Lehman period, the interest rate of the US dollar became low on the forward contract because of its role as international currency. However, in the Euro crisis, that of the Sterling pound became equally low, while those of the other European currencies such as the Danish kroner increased their liquidity premium. In this paper, we examined why the Sterling pound and the Danish kroner had shown such asymmetric features in the two crises. The regression results suggested that there was a structural break in the determinants of deviations from covered interest parity (CIP) condition during the crises. In particular, we found that strong Sterling pound in the Euro crisis has emerged through substituting Euro's role as an international liquidity.

It was in late 2009 when fears of a sovereign debt crisis developed among investors

concerning Greece's ability to meet its debt obligations due to strong increase in government debt levels. This led to a crisis of confidence, indicated by a widening of bond yield spreads and the cost of risk insurance on credit default swaps in several European countries such as Ireland, Portugal, Italy, Greece, and Spain. However, the effects of the crisis were not symmetric across European currencies. For the Danish kroner, its tight linkage to Euro is critical in the regional transactions. Consequently, increased bid-ask spread in the Euro increased Danish precautionary demand for the Euro and made the Euro's interest rate lower than the Kroner's rate. In contrast, due to less reliance on the Euro in the UK, smaller liquidity risk in the Sterling pound in the money markets shifted precautionary demand from the Euro to the Sterling pound in the Euro crisis. As a result, the increased EU banks' credit risk enhanced the role of the Sterling pound as a substitute for the Euro in international transactions. The strong Sterling pound in the Euro crisis may be attributable to the fact that London is the largest money center in the world.

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Table 1. Currency Shares of Geographical Distribution of Foreign Exchange Market Turnover

Country	1995	1998	2001	2004	2007	2010	2013
Australia	2.5	2.3	3.2	4.1	4.1	3.8	2.7
Denmark	1.9	1.3	1.4	1.6	2.1	2.4	1.5
France	3.8	3.7	2.9	2.6	3.0	3.0	2.8
Germany	4.8	4.7	5.4	4.6	2.4	2.1	1.7
Hong Kong SAR	5.6	3.8	4.0	4.1	4.2	4.7	4.1
Japan	10.3	7.0	9.0	8.0	5.8	6.2	5.6
Singapore	6.6	6.9	6.1	5.1	5.6	5.3	5.7
Switzerland	5.4	4.4	4.5	3.3	5.9	5.2	3.2
United Kingdom	29.3	32.6	32.0	32.0	34.6	36.7	40.9
United States	16.3	18.3	16.1	19.1	17.4	17.9	18.9
others	13.5	15.0	15.2	15.6	14.8	12.8	12.9
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Note) Daily averages in April, in billions of US dollars and percentages.

Table 2. Basic Test Statistics for Daily Credit Risk Measures for the Two Sub-sample Periods

(1) First Sample (from Jan 2, 2008 to Dec. 31, 2009)

	US Dollar	Euro	Sterling pound	Kroner	Swiss franc	Japanese yen
Mean	0.79	0.71	0.90	0.87	0.35	0.42
Median	0.72	0.63	0.79	0.69	0.30	0.40
Maximum	3.64	1.95	3.00	2.00	1.76	0.81
Minimum	0.07	0.21	0.15	0.32	0.19	0.18
Std. Dev.	0.65	0.40	0.59	0.40	0.21	0.14
Skewness	1.85	1.22	0.83	0.98	3.38	0.36
Kurtosis	7.26	4.02	3.07	2.96	16.85	2.94
Obervations	522	522	522	522	294	522

(2) Second Sample (from Jan 2, 2010 to Feb. 15, 2012)

	US Dollar	Euro	Sterling pound	Danish krone	Swiss franc	Japanese yen
Mean	0.21	0.36	0.29	0.40	0.09	0.13
Median	0.16	0.25	0.24	0.42	0.07	0.13
Maximum	0.51	0.93	0.60	0.71	0.40	0.17
Minimum	0.06	0.09	0.15	−0.05	−0.01	0.09
Std. Dev.	0.12	0.24	0.12	0.19	0.06	0.02
Skewness	1.00	1.19	1.25	−0.38	1.38	−0.25
Kurtosis	2.86	2.83	3.35	2.08	4.80	2.34
Obervations	553	553	553	553	553	553

Table 3. Basic Test Statistics for Daily Banks Sector and Sovereign CDS

(1) First Sample (from Jan 2, 2008 to Dec. 31, 2009)

	US bank	EU bank	UK bank
Mean	191.9	143.3	141.6
Median	170.6	126.4	137.7
Maximum	596.0	319.5	235.2
Minimum	86.5	49.8	70.7
Std. Dev.	78.7	57.1	34.8
Skewness	1.3	1.1	0.4
Kurtosis	5.4	3.9	2.6
Obervations	522	522	522

sovereign	USA	Germany	UK	France	Italy	Spain	Ireland	Denmark
Mean	31.1	25.7	56.9	30.2	78.8	67.2	127.7	43.1
Median	25.9	22.5	52.1	25.2	63.2	61.0	139.8	27.0
Maximum	95.0	92.5	165.0	96.5	190.0	163.5	390.0	150.0
Minimum	6.0	5.2	7.4	6.7	21.1	19.8	12.8	5.4
Std. Dev.	23.0	20.0	41.8	21.2	46.8	33.9	95.2	40.2
Skewness	1.0	1.2	0.7	1.1	0.9	0.7	0.5	1.1
Kurtosis	3.2	4.3	2.5	3.7	2.7	2.7	2.5	2.9
Obervations	522	522	522	522	522	522	522	522

(2) Second Sample (from Jan 2, 2010 to Feb. 15, 2012)

	US bank	EU bank	UK bank
Mean	138.6	297.7	166.8
Median	122.0	296.6	153.9
Maximum	264.9	606.4	295.4
Minimum	82.9	97.0	102.7
Std. Dev.	45.2	118.0	44.9
Skewness	1.1	0.4	1.0
Kurtosis	3.0	2.4	2.9
Obervations	553	553	553

sovereign	USA	Germany	UK	France	Italy	Spain	Ireland	Denmark
Mean	44.7	39.4	67.1	79.8	199.7	214.8	524.8	50.6
Median	44.7	34.9	67.2	65.7	146.0	194.8	588.3	32.9
Maximum	65.0	79.3	95.0	171.6	498.7	399.6	1249.3	147.1
Minimum	31.9	18.0	42.4	30.0	72.0	73.5	114.9	18.9
Std. Dev.	5.8	13.6	12.3	34.2	116.5	75.8	255.7	35.8
Skewness	0.3	0.7	0.1	1.0	1.1	0.3	−0.1	1.2
Kurtosis	2.7	2.5	2.0	2.7	2.8	2.2	2.1	2.8
Obervations	553	553	553	553	553	553	553	553

Table 4. Basic Test Statistics for Daily bid-ask spreads of three-month forward rates

(1) First Sample (from Jan 2, 2008 to Dec. 31, 2009)

	Euro	Sterling pound	Danish kroner	Swiss franc	Japanese yen
Mean	0.033	0.038	0.067	0.071	0.051
Median	0.027	0.032	0.055	0.064	0.041
Maximum	0.118	0.163	0.176	0.208	0.193
Minimum	0.021	0.022	0.028	0.049	0.031
Std. Dev.	0.016	0.019	0.031	0.023	0.026
Skewness	2.863	3.252	1.164	2.383	2.916
Kurtosis	12.201	15.741	3.429	9.378	12.508
Obervations	522	522	522	522	522

(2) Second Sample (from Jan 2, 2010 to Feb. 15, 2012)

	Euro	Sterling pound	Danish krone	Swiss franc	Japanese yen
Mean	0.031	0.032	0.046	0.076	0.050
Median	0.031	0.032	0.045	0.073	0.051
Maximum	0.046	0.049	0.074	0.144	0.071
Minimum	0.022	0.025	0.027	0.052	0.033
Std. Dev.	0.005	0.004	0.010	0.015	0.008
Skewness	0.268	0.556	0.256	1.586	0.161
Kurtosis	2.437	3.631	2.081	6.773	2.487
Obervations	553	553	553	553	553

Table 5. The estimated results of Equation (1)

(1) First Sample (from Jan 2, 2008 to Dec. 31, 2009)

		Sterling pound		Danish krone	
	Constant term	−0.002	−0.001	−0.062	−0.021
		(−0.031)	(−0.008)	(−0.856)	(−0.289)
Lagged dependent var.	Dependent var. (-1)	0.832	0.827	0.541	0.573
		(10.507)***	(10.905)***	(12.294)***	(13.782)***
	Dependent var. (-2)	−0.090	−0.083	0.132	0.101
		(−1.176)	(−1.133)	(2.506)**	(1.830)*
Measure of currency-specific credit risk	Euro LIBOR spread	0.164	0.160	0.256	0.257
		(3.058)***	(2.995)***	(4.724)***	(4.871)***
	Dollar LIBOR spread	−0.048	−0.055	0.029	0.000
		(−1.663)*	(−1.986)**	(1.124)	(0.985)
	Local LIBOR spread	−0.096	−0.095	−0.179	−0.171
		(−2.173)**	(−2.233)**	(−3.347)***	(−3.126)***
Measure of country-specific bank credit risk	EU bank CDS/100	0.009	0.015	−0.033	−0.014
		(0.300)	(0.574)	(−1.623)*	(−0.666)
	US bank CDS/100	−0.001	0.000	0.001	0.000
		(−0.153)	(−0.032)	(0.291)	(0.028)
	UK bank CDS/100	−0.004	−0.009	0.012	−0.002
		(−0.087)	(−0.189)	(0.374)	(−0.067)
Measure of country-specific sovereign risk	Log(Ireland CDS)	0.007	0.008	0.046	0.032
		(0.167)	(0.215)	(2.695)***	(1.940)*
	Log(Italy CDS)	−0.001	−0.002	−0.021	−0.031
		(−0.023)	(−0.067)	(−0.786)	(−1.187)
	Log(local CDS)	−0.021	−0.024	−0.005	0.012
		(−0.370)	(−0.477)	(−0.186)	(0.415)
Market risk	VIX	0.001	0.001	0.002	0.002
		(0.866)	(0.846)	(1.443)	(1.594)
Measure of market liquidity	3M Euro-dollar	−0.420		−1.448	
		(−0.580)		(−2.446)**	
	3M local-dollar	−0.043		0.599	
		(−0.069)		(2.961)***	
	Adjusted R-squared	0.75	0.75	0.92	0.91
	Observation number	521	521	522	522

(2) Second Sample (from Jan 4, 2010 to Feb. 15, 2012)

		Sterling pound		Danish krone	
	Constant term	−0.074	−0.074	0.115	0.119
		(−0.890)	(−0.916)	' (2.067)**	' (2.269)**
Lagged dependent var.	Dependent var. (-1)	0.791	0.776	0.731	0.729
		(11.255)***	(11.137)***	(11.109)***	(10.980)***
	Dependent var. (-2)	0.100	0.119	0.108	0.111
		(1.283)	(1.521)	(1.890)*	(1.919)*
Measure of currency-specific credit risk	Euro LIBOR spread	0.038	0.039	0.030	0.027
		(1.569)	(1.554)	(1.270)	(1.115)
	Dollar LIBOR spread	0.062	0.065	0.019	0.018
		(2.013)**	(1,952)*	(0.831)	(0.862)
	Local LIBOR spread	−0.083	−0.089	−0.057	−0.056
		(−1.788)*	(−1.802)*	(−1.966)**	(−1.961)**
Measure of country-specific bank credit risk	EU bank CDS/100	−0.022	−0.021	0.019	0.019
		(−3.123)***	(−3.074)***	(3.343)***	(3.507)***
	US bank CDS/100	0.000	0.002	−0.013	−0.012
		(0.013)	(0.145)	(−0.920)	(−0.835)
	UK bank CDS/100	−0.006	−0.003	−0.027	−0.027
		(−0.292)	(−0.137)	(−1.310)	(−1.311)
Measure of country-specific sovereign risk	Log(Ireland CDS)	0.027	0.026	−0.018	−0.017
		(2.433)**	(2.369)**	(−1.639)	(−1.640)
	Log(Italy CDS)	−0.009	−0.010	0.012	0.011
		(−0.800)	(−0903)	(1.038)	(0.995)
	Log(local CDS)	0.009	0.006	−0.014	−0.014
		(0.514)	(0.340)	(−2.162)**	(−2.159)**
Market risk	VIX	−0.001	−0.001	0.001	0.001
		(−1.569)	(−1.736)*	(1.951)*	(1.952)*
Measure of market liquidity	3M Euro-dollar	0.437		−0.178	
		(1.247)		(−0.523)	
	3M local-dollar	−0.934		0.168	
		(−2.537)**		(1.037)	
	Adjusted R-squared	0.960	0.960	0.816	0.817
	Observation number	553	553	553	553

Notes: 1) In the table, "local" means either the Sterling pound or UK for the Sterling pound and either the Danish krone or Denmark for the Danish krone.

2) t-value is in the parentheses. *** = 1% significance level, ** = 5% significance level, * = 10% significance level.

Table 6. Multiple Breakpoint Tests

(1) The Sterling Pound

Break dates:		
	Sequential	Repartition
1	10/22/2008	9/29/2008
2	6/04/2009	6/19/2009
3	7/06/2011	8/27/2010
4	8/27/2010	7/06/2011

Break Test	F-statistic	Scaled F-statistic	Critical Value**
0 vs. 1 *	3.64	54.61	27.03
1 vs. 2 *	2.24	33.63	29.24
2 vs. 3 *	2.46	36.96	30.45
3 vs. 4 *	2.29	34.41	31.45
4 vs. 5	0	0	32.12

(2) The Danish Krone

Break dates:		
	Sequential	Repartition
1	1/06/2009	1/05/2009
2	12/29/2009	8/25/2009
3	12/28/2010	12/28/2010

Break Test	F-statistic	Scaled F-statistic	Critical Value**
0 vs. 1 *	3.82	57.25	27.03
1 vs. 2 *	2.63	39.48	29.24
2 vs. 3 *	2.75	41.27	30.45
3 vs. 4	0	0	31.45

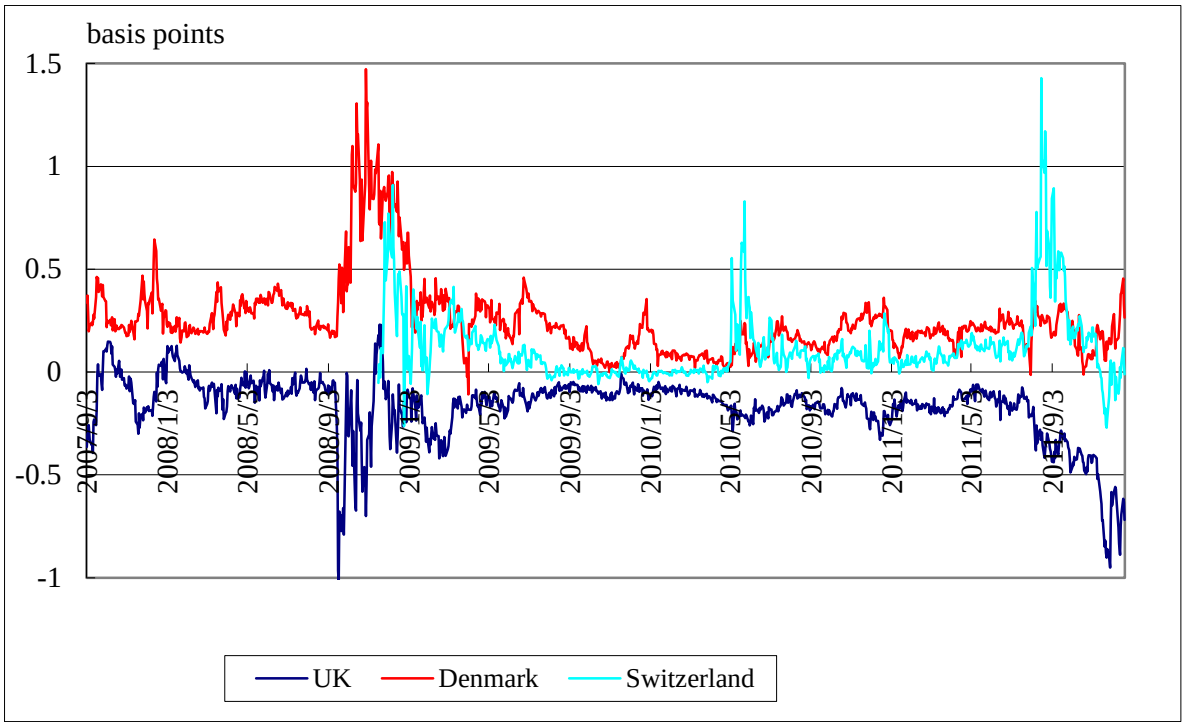
Note: Significant at the 0.05 level. Bai-Perron (Econometric Journal, 2003) critical values.

Table 7. The estimated results under Alternative Sample Split

	First sub-sample		Second sub-sample	
	S. pound	Danish krone	S. pound	Danish krone
Constant term	−0.059	−0.059	0.300	0.291
	(−0.601)	'(−1.431)	(2.320)**	(3.961)***
Dependent var. (-1)	0.827	0.402	0.487	0.522
	(10.405)***	(6.611)***	(3.414)***	(6.177)***
Dependent var. (-2)	−0.120	0.022	0.278	0.174
	(−1.510)	(0.373)	(3.414)***	(2.660)***
Euro LIBOR spread	0.258	0.302	0.060	0.135
	(3.677)***	(3.039)***	(0.668)	(3.098)***
Dollar LIBOR spread	−0.055	0.041	0.093	−0.012
	(−1.696)*	(1.044)	(0.668)	(−0.289)
Local LIBOR spread	−0.183	−0.188	0.065	−0.213
	(−3.037)***	(−2.099)**	(0.668)	(−4.634)***
EU bank CDS/100	−0.016	0.043	−0.007	0.018
	(−0.406)	(0.636)	(−2.961)**	(3.964)***
US bank CDS/100	0.001	−0.008	0.007	−0.034
	(0.088)	(−1.023)	(0.668)	(−1.300)
UK bank CDS/100	0.015	−0.069	−0.016	0.033
	(0.249)	(−0.948)	(−0.278)	(1.190)
Log(Ireland CDS)	0.060	0.037	−0.010	−0.023
	(0.985)	(0.668)	(−0.278)	(−1.986)**
Log(Italy CDS)	−0.012	−0.007	−0.010	−0.015
	(−0.278)	(−0.087)	(−0.278)	(−1.014)
Log(local CDS)	−0.051	−0.008	−0.041	−0.013
	(−0.672)	(−0.265)	(−0.278)	(−1.017)
VIX	0.001	0.004	−0.002	0.002
	(0.768)	(1.832)*	(−2.293)**	(2.057)**
3M Euro-dollar	−0.412	−2.094	0.084	−0.241
	(−0.537)	(−2.961)***	(0.668)	(−0.706)
3M local-dollar	0.213	1.168	−1.090	0.032
	(0.307)	(2.257)**	(−2.293)**	(0.193)
Adjusted R-squared	0.751	0.926	0.731	0.903
Observation number	372	264	238	261

t-value is in the parentheses. *** = 1% significance level, ** = 5% significance level, * = 10% significance level.

Figure 1. Deviations from the CIP condition between Euro and three currencies



This figure depicts daily deviations from CIP condition between Euro and each of the three non-Euro currencies. The upward deviations imply that Euro had lower interest rate on the forward market.