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Information Flow between Sovereign CDS and Dollar-Yen Currency Option Markets in the Sovereign Debt Crisis of 2009-2011

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Abstract

While the US dollar and Japanese yen are considered as safe-haven currencies, both their sovereign credit default swap (CDS) spreads and exchange rate have varied in a wide range since late 2007. This raises the question of interconnectivity between the anticipated sovereign credit risk and the market expectation of the dollar-yen exchange rate. This paper shows evidence of information flow from the sovereign CDS market to the dollar-yen currency option market during the sovereign debt crisis from September 2009 to August 2011 when concerns about sovereign credit risks in the developed economies were triggered. The impact of the US sovereign credit risk on the risk reversal is a separable risk factor in driving the market expectation of the dollar-yen exchange rate after controlling other macro-financial variables. While the Japanese sovereign CDS spread was higher than its US counterpart, its impact on the risk reversal was not significant.

Keywords: Sovereign Risk, Currency Options, Credit Default Swaps, Fiscal Situation

JEL Classifications: F31, G13

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1. Introduction

A change in the credit risk of a sovereign borrower anticipated by financial markets is reflected in its sovereign credit default swap (CDS) spread, which is a direct measure of the creditworthiness of the underlying issuer.[1] A sovereign CDS is an over-the-counter credit protection contract in which a protection seller pays compensation to a protection buyer to make a payment in the case of a pre-defined credit event. For credit protection buyers who pay a fixed premium called the CDS spread, the CDS market offers the opportunity to reduce credit risk. For protection sellers, it offers the opportunity to take credit exposure to an entity and earn income without having to fund the position. The sovereign CDS spread can be considered as a measure of a country's economic-political stability, which is linked to country-specific macro-economic variables, such as output growth, foreign exchange reserves, budget deficit, real effective exchange rate deviation, and foreign direct investment. Increased sovereign risk due to economic-political instability would lead investors to sell securities denominated in the country's currency and to repatriate funds, hence putting downward pressure on and heightening volatility in the currency.[2]

Because of the relationship between sovereign risk and exchange rate stability, the interactions between the sovereign CDS market and the currency market have been studied recently for the developing countries and the euro area. In particular, anticipated changes in the realised volatility of currency returns by market participants are reflected in the prices of currency options. Carr and Wu (2007) investigate the relationship between currency option-implied volatilities and sovereign creditworthiness for Mexico and Brazil from 2002-2005. They find that the level and skew of the option-implied volatility display significant co-movement with the sovereign CDS spreads of the two countries. This suggests that the currency option market has consistently set prices considering the probability of a currency crash triggered by a corresponding sovereign default of the two countries. Hui and Chung (2011) show that the creditworthiness of euro-area countries distinct from other macro-financial factors can affect market expectations on the stability of the euro during the European sovereign debt crisis. They find evidence of information flow from the sovereign CDS market to the dollar-euro currency option market in the crisis.

Although the US sovereign CDS spread has remained low compared with those of fiscally distressed euro-area countries, the 5-year US CDS spread surged from the level of 10 bps to nearly 100 bps in February 2009 as shown in Figure 1, reflecting that the failure of IndyMac Bank, the Lehman Brothers bankruptcy and AIG's attempts to negotiate a bridge loan from the Federal Reserve could have affected the long-term fiscal situation of the US government. The CDS spread then dropped to the level of 20 bps in June 2009 after extraordinary fiscal and monetary policy efforts taken in the US.

[1] The sovereign CDS market expanded rapidly in 2009 and 2010. The gross notion of protection was around US$2 trillion as of 2010. See the IMF's Global Financial Stability Report (Meeting New Challenges to Stability and Building a Safer System, April 2010).

[2] The interaction between sovereign risk of countries and sudden depreciation of their currencies has long been the subject of interest in international finance including those of Eichergreen et al. (1996), Frankel and Rose (1996), Kaminsky et al. (1998), and Kumar et al. (2003), who use macro-economic indicators to estimate the probability of currency crashes. These studies focus on developing economies.

However, the spread had increased again to the range of 40 and 60 bps since late 2009 when the European sovereign debt crisis emerged. In the summer of 2011, the credit rating agencies including the Fitch, Moody's and Standard & Poor's (S&P's) expressed concerns about very large budget deficits and rising indebtedness of the US government. The CDS spread jumped to 64 bps in late July 2011 as the unresolved US debt-ceiling discussions raised the spectre of a potential technical default by the federal government (failure to pay the interest and/or principal of US treasury securities on time).[3]

Figure 1 shows broadly co-movement between the Japanese and US sovereign CDS spreads during the period between December 2007 and June 2009. Since late 2009, the Japanese sovereign CDS has been traded in a range of 50 to 120 bps and consistently higher than its US counterpart. The higher CDS spread reflected a deterioration in Japan's fiscal balance and market participants seemed to be more concerned about the fiscal situation.

Figure 2 reports the net notional amounts outstanding (i.e., net protection bought) and average daily amounts of transactions of the CDS contracts of the US, Japan and the five highly indebted European counties including Greece, Ireland, Italy, Portugal and Spain as at 21 October 2011. Both the US and Japanese sovereign CDS contracts had a similar total net notional value of about US$9 billion which is relatively small compared to those of Italy, Spain and Portugal, but comparable to those of Greece and Ireland.[4] While the amounts of net notional outstanding of the US and Japanese sovereign CDS are limited, changes in their spreads are commonly used by policy makers to monitor for signals of concerns about their sovereign risks anticipated by market participants.[5] Given that their sovereign CDS spreads are market-implied indicators of sovereign risks and could have implications on exchange rate stability, this raises the question of interconnectivity between the sovereign CDS market and the currency option market of the US and Japan.

This paper studies how the US sovereign risk affects market expectations on the US dollar exchange rate against the Japanese yen embedded in their currency options during the crisis period from December 2007 to August 2011 when the US dollar had once depreciated about 30% against the yen (see Figure 3). The US dollar exchange rate movements are quite inconsistent with the conventional wisdom that the dollar together with the Japanese yen and the Swiss franc are safe-haven currencies during financial crises according to the findings in Ranaldo and Söderlind (2010) and Kohler (2010).[6]

The market expectation of the dollar exchange rate is reflected by the price of a risk reversal. The risk reversal is a directional option strategy that takes the view of the skewness of the exchange rate

[3] Despite a settlement to raise the borrowing limit, S&P's lowered the credit rating of the US from AAA to AA+ on 5 August 2011, deciding pessimistic about its fiscal outlook.

[4] Details of the structure of the sovereign CDS market are in Pan and Singleton (2008).

[5] For example, see Box 1.2 "How Concerned are Markets About US Sovereign Risks" in the IMF's September 2011 Global Financial Stability Report. However, the US sovereign CDS spread is not considered very reliable for extracting mathematical default probability.

[6] There is no well-accepted definition of a safe haven asset. It could mean an asset with low risk or high liquidity and have a common characteristic that one would expect the relative price of such an asset to increase during crises.

distribution by simultaneously buying an out-of-the-money put and selling an out-of-the-money call.[7] It measures the implied volatility difference between an out-of-the-money put and call at the same (absolute) delta. Figure 3 shows the positive risk reversals of dollar-yen options during the period from late 2007 to August 2011. This reflects that the dollar-put implied volatility is higher than the dollar-call implied volatility.[8] The asymmetry in the implied volatility occurs because market participants think that a depreciation of the dollar is more likely than an appreciation of the same size. One reason for such asymmetry in the expectation of the dollar-yen exchange rate is that only 5% of the Japanese government bonds are held by foreign investors, which is much smaller than 48% of the US Treasury securities held by foreign investors.[9] As foreign investors are more likely to sell a country's government bonds with rising default risk compared with home investors, when both the US and Japan's sovereign credit risk is rising, the US Treasury securities would be under larger selling pressure by foreign investors relative to the Japanese government bonds. This makes the yen safer than the dollar.

In view of these observations, first we study the information transmission between the sovereign CDS and currency option markets to examine whether currency option prices anticipate information of sovereign credit risk from CDS spreads. Secondly, we investigate whether sovereign credit risk is an important determinant of the risk reversal, after controlling for the interest rate differential, global risk appetite, funding liquidity constraint, and macro-financial condition.

This paper demonstrates that interconnectivity not only appears between the corporate credit market and the corresponding stock (or stock option) market, but also exists between the sovereign CDS market and the currency option market. In the corporate sector, Acharya and Johnson (2007) find that the corporate CDS market leads the stock market to anticipate adverse credit information of the reference firm and this finding is linked to informed-trading in credit derivatives. This is reflected by incremental information flow from the corporate CDS market to the stock market. Cremers et al. (2008) show that the implied volatility skews of individual stock options are an important determinant of time-series and cross-sectional variations in corporate yield spreads. Cao et al. (2010) document that implied volatility of deep out-of-the-money put options of stocks is closely related to corporate CDS spreads, because the options provide investors with similar protections against downside risk. They conclude that stock options play an important role in the price discovery process for firms' credit risk.

This paper is organised as follows. Section 2 discusses the data and examines the information transmission between the sovereign CDS and dollar-yen currency option markets. Section 3 studies the contemporaneous interaction between the two markets based on an econometric analysis. Section 4 contains the conclusion.

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7 A positive (negative) risk reversal implies that the risk-neutral exchange rate distribution is negatively (positively) skewed.

8 A dollar put (call) option against the yen here is a European option of selling (buying) dollars at the contractual option strike price in an exchange of yens at the option maturity.

9 The figure for the Japanese government bonds is from Bank of Japan as at March 2011 and the figure for the US Treasury securities is from the Bureau of Public Debt as at June 2011.

2. Information Flow from Sovereign CDS Market to Currency Option Market

We obtain daily over-the-counter 10-delta risk reversals of dollar-yen options at two fixed maturities of 1 and 3 months, and the 5-year sovereign CDS spreads of the US and Japan from 11 December 2007 to 15 August 2011.[10] The tenors of these derivative instruments are commonly used as benchmarks of their respective markets. To control the structural differences before and after the onset of the European sovereign debt crisis, which triggered concerns about sovereign risks in developed economies, we split the sample period into two sub-periods. The first period is from 11 December 2007 to 16 September 2009 (before the sovereign debt crisis began), and the second period is from 17 September 2009 (before the new government came to power after elections in Greece in October 2009) to 15 August 2011 (the crisis period). All time series are first-differenced to ensure their stationarity in estimation. Table 1 provides summary statistics of these time series. As the 1- and 3-month risk reversals are highly correlated as shown in Table 1, we only present estimations results based on the 3-month risk reversal in this and following sections.[11]

We use the Granger causality test and the cross-correlation test to assess preliminarily the lead-lag relationship between the sovereign CDS spreads and the risk reversal. The Granger causality test checks whether the coefficients of one variable in the preceding periods are significant in the regression of the other in the current period.[12] The cross correlation test is similar to the Granger causality test, but it tests whether the correlations between one variable in the preceding periods and the other in the current period are significant or not.[13] If the lead-lag relationship is clear (i.e., the sovereign CDS spread leads the risk reversal), both tests will yield the same finding that the sovereign CDS spread in the preceding periods will "Granger cause" and be cross-correlated with the risk reversal in the current period.

The test results presented in Table 2 show preliminary evidence that the US sovereign CDS spread leads the risk reversal in the second sample period only. In the first sample period, the Granger causality test suggests the risk reversal may "Granger cause" the US sovereign CDS spread, but the cross correlation test finds no significant correlations between the two variables. Regarding the Japanese sovereign CDS spread, both tests demonstrate that the spread and risk reversal may influence each other in the second sample period. The risk reversal, however, leads the Japanese sovereign CDS spread in the first sample period.[14]

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[10] The currency option and CDS data are from JPMorgan Chase and Bloomberg respectively. The US sovereign CDS information is only available in Bloomberg since 11 December 2007.

[11] The estimation results using the 1-month risk reversal, which are similar to those using the 3-month risk reversal, are available upon request.

[12] Specifically, it uses an F-test to test the null hypothesis of "the coefficients are jointly equal to zero" in the regression.

[13] Specifically, it uses a chi-square test to check the null hypothesis of "the cross correlation are jointly equal to zero". This test is more general and can be used to cover more possible types of causal interactions between two variables. Further discussion is in Pierce and Haugh (1977).

[14] For the Japan sovereign CDS market, both tests suggest the risk reversal leads the sovereign CDS spreads in the first period, but an inconclusive result in the second period in view of the two time series significantly influencing each other.

The preliminary results reveal a potential lead-lag relationship between the sovereign CDS spreads and the risk reversal, which suggests an information flow from the sovereign CDS market to the dollar-yen option market. To test the existence of any information flow more rigorously, we follow the methodology in Acharya and Johnson (2007) to consider the two markets possessing two different but inter-dependent information sets.[15] By controlling the contemporaneous interaction between the two markets, they extract the market-specific innovations and study the structure of information flow between the two markets. These innovations are interpreted as the market-specific information arrival to the particular markets. They are the market-specific information arrivals in the two markets in addition to the market-wide information set.[16] If the sovereign CDS market acquires forward-looking information and affects the risk reversal of dollar-yen options, the price innovations of the US and Japanese sovereign CDS spreads should have explanatory power on the future changes in the risk reversal. We filter the market-specific price innovations in the sovereign CDS spreads by the following regression:

$$\Delta CDS_{i,t} = a + b\Delta RR_t + \sum_{k=1}^{n} c_k \Delta CDS_{i,t-k} + \varepsilon_{CDS_i,t} \quad (1)$$

where ΔRR_t are the changes in the 10-delta risk reversal (the implied volatility of a US dollar put (yen call) minus and that of a US dollar call (yen put) at the 10% delta), $\Delta CDS_{i,t}$ are the changes in the US and Japanese CDS spreads, for $i = 1,2.$[17] The lagged changes in CDS spread capture the lagged information transmission within the sovereign CDS market. In the regression, the market-specific innovation $\varepsilon_{CDS_i,t}$ is identified as an independent information arrival that is not anticipated by the currency option market at time t.

We estimate the information flow from the sovereign CDS market to the currency option market using the lagged influences of $\varepsilon_{CDS_i,t}$ on the implied volatility in the following regression:

$$\Delta RR_t = \alpha + \sum_{k=1}^{n} \beta_k \varepsilon_{CDS_i,t-k} + \sum_{k=1}^{n} \gamma_k \Delta RR_{t-k} + \varepsilon_{VOL,t}\,, \quad (2)$$

[15] Acharya and Johnson (2007) empirically investigate whether the corporate CDS market acquires information prior to the stock market.

[16] Formally, we consider a probability space $(\Omega, \Im_t, Q)$, where Q is the risk-neutral measure in an arbitrage-free economy, $\Im_t$ is the filtration generated by the underlying state variables (the overall financial market) in such a way that $\Im_t = G_t \vee H_t$, where G_t and H_t are the information sets of the sovereign CDS market and currency option market respectively.

[17] The risk-neutral probability of the underlying ending in-the-money is roughly equal to the delta of the option. For example, a 10-delta put option has approximately 10% probability of in-the-money at maturity. This approximation holds well for a short time to maturity.

as reflected by the loading coefficients β_k , $k = 1,2,...n$. Acharya and Johnson (2007) use the statistical significance of the point estimate $I = \sum_{k=1}^{n} \beta_k$ to assess the intensity of an information flow. If the information flow is large and permanent, I should be significantly positive.[18]

Similarly, we analyse the reverse information flow from the currency option market to the sovereign CDS market by the regressions:

$$\Delta RR_t = \tilde{a} + \tilde{b}\Delta CDS_{i,t} + \sum_{k=1}^{n} \tilde{c}_k \Delta RR_{t-k} + \tilde{\varepsilon}_{VOL,t}, \quad (3)$$

$$\Delta CDS_{i,t} = \tilde{\alpha} + \sum_{k=1}^{n} \tilde{\beta}_k \tilde{\varepsilon}_{VOL_i,t-k} + \sum_{k=1}^{n} \tilde{\gamma}_k \Delta CDS_{i,t-k} + \tilde{\varepsilon}_{CDS,t}, \quad (4)$$

where the estimate $\tilde{I} = \sum_{k=1}^{n} \tilde{\beta}_k$ measures the intensity of reverse information flow. When there is a robust one-way information flow from the CDS market to the currency option market, I should be significantly positive and $\tilde{I}$ should be statistically insignificant.

We estimate Eqs. (1) to (4) using daily data for the two sample periods. Table 3 shows that there is substantial information flow from the sovereign CDS market to the currency option market with significant positive estimates of I during the second period when both the US and Japanese sovereign CDS spreads increased from the low levels. The reverse information flow, however, is insignificant. This means that the information flow, which is transient in nature and conditional to the adverse development of sovereign creditworthiness, is primarily from the sovereign CDS market to the dollar-yen currency option market. The risk reversal of the currency option prices, which measures the expectation of the dollar-yen exchange rate, responds to adverse information revealed in the sovereign CDS market. While the size of the CDS market is much smaller than that of the currency option market in terms of outstanding amounts, currency option prices contain information transmitted from the sovereign CDS spreads.[19]

However, in the first sample estimation, the information flow between the two markets is minimal and the direction of flow is mixed. As the information flow from the sovereign CDS market to the currency option market is concentrated during the sovereign debt crisis period (i.e., the second sample period), our finding is consistent with the existence of hedging by market participants who might initially use

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[18] We employ the Wald test for coefficient restriction with the null hypothesis $\sum_{k=1}^{n} \beta_k = 0$. The number of lags is chosen to be n = 5 based on the autocorrelation structures of the CDS spreads and risk reversal.

[19] According to the BIS, the notional amounts outstanding of currency options on the US dollar and yen were US$9,615 billion and US$4,200 billion respectively at end-June 2010, which were the largest among the currencies. See BIS, Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity in 2010 – Final Results.

the sovereign CDS to hedge the downside risks of their sovereign bond portfolios. When the concern about sovereign credit risk intensified, they might buy dollar-yen options to reduce potential losses due to the crash risk of the currencies. With the depreciation of the dollar and the positive risk reversals during the period, the currency hedge could be buying out-of-the-money dollar-put options and thus incorporate the US sovereign credit risk into the risk premium of dollar-yen options. In the following section, we investigate whether the sovereign credit risk is an important determinant of the risk reversal, after controlling for the interest rate differential, global risk appetite, funding liquidity constraint, and macro-financial condition.

3. Cross-Sectional Interaction between CDS Spreads and Currency Option Prices

The previous section shows the presence of interconnectivity and information flow between the sovereign CDS market and currency option market. To understand better the economic sources of such linkage, we focus on the cross-sectional interaction and use regression analysis to study how the market expectation of the dollar-yen exchange rate anticipated in the risk reversal by currency option market participants is attributed to sovereign credit risk of the US and Japan. We test the following three hypotheses:

(i) the impact of sovereign credit risk on the risk reversal is driven by the US but not Japan;
(ii) the US sovereign credit risk is a separable risk factor in driving the market expectation of the dollar-yen exchange rate after controlling other macro-financial variables; and
(iii) the impact of the US sovereign credit risk is predominantly during the sovereign debt crisis from September 2009 to August 2011, but not before.

Recent research finds that sovereign credit risk interacts strongly with global and regional financial risk factors. Longstaff et al. (2010) show that sovereign CDS spreads are primarily driven by common factors, including the US stock and high-yield bond markets and global risk premiums, whereas Pan and Singleton (2008) find that the spreads are related to investors' risk appetite associated with global event risk, financial market volatility, and macroeconomic policy. Therefore, examining whether sovereign risk represents a separable risk factor different from other economic and financial factors in driving the risk reversal of dollar-yen currency options is important. To address this issue, we employ a set of macro-financial variables as control determinants of the 10-delta risk reversal, including the following factors:[20]

(i) *Interest rate differential*. In a currency carry trade, an investor borrows in a low yielding currency and invests in a high yielding currency. To realise the carry in the trade, investors are required to hold the position for some time. With the yen interest rate r_{JPY} which remained near zero during the two sample periods, the return of the carry trade is proportional

[20] We obtain data for these additional variables from Bloomberg.

to $(r_{USD} - r_{JPY})T$, where r_{USD} is the dollar interest rate and *T* is the holding period. The risk to the carry trade is an adverse price movement in the level of the exchange rate, i.e., a currency crash. As found in Brunnermeier et al. (2009), the expected exchange rate movements between high-interest-rate and low-interest-rate currencies are negatively skewed due to the crash risk of sudden unwinding of carry trades and reflected in the risk reversals of their out-of-the-money currency options. Therefore, if $(r_{USD} - r_{JPY})$ increases, the risk reversal is expected to increase as a result of hedging against the crash risk. We use the 1-month US dollar and Japanese yen LIBORs for the interest rate differential.

(ii) *US dollar volatility.* The implied volatility of an exchange rate is essentially linked to the anticipated uncertainty on the values of both currencies in the pair. Therefore, we use the US dollar index (DXY), a weighted average of the dollar's value relative to a basket of foreign currencies, to capture the actual volatility attributable to the dollar factor. We proxy the volatility of the US dollar (R_{USD}^2) as the ex-post squared return of the index.

(iii) *Global risk appetite.* We use the CBOE VIX volatility index (*VIX*), the market volatility of the US S&P 500 index, to gauge the global risk appetite in the financial market.[21] An increase in the VIX index is usually associated with heightened volatility across different asset classes in particular equities. Currency option-implied volatility shares commonality with the VIX index as a measure of investors' aversion to volatility exposure and hence their willingness to put capital at risk. A positive relationship between the 10-delta risk reversal and the VIX implies that the currency option market is more risk-averse against the dollar than the yen.

(iv) *Funding liquidity constraint.* Another potential determinant of the risk reversal is the sudden unwinding of carry trades. We follow Brunnermeier et al. (2009) and use the US dollar TED spread (*TED*), the difference between the 3-month interbank rate and the yield of the 3-month Treasury bill, to capture traders' funding liquidity constraint. When funding liquidity is tight, as reflected by a widened TED spread, traders are forced to unwind their carry-trade positions and repatriate funds to a safe-haven currency, i.e., the yen in our study. This suggests an expected positive relationship between the TED spread and the risk reversal.

(v) *Macro-financial condition.* To capture the broad changes in the macro-financial condition, we include two measures from the stock and bond markets that have been used by Collin-Dufresne et al. (2001), Cremers et al. (2008), and Cao et al. (2010). Regarding the stock market variables, we use the weekly returns of the S&P 500 index (*SPX*) and Nikkei 225 (*NIK*). Conventionally, a negative US stock market return indicates a weaker US economic outlook and puts downward pressure on the dollar, i.e., higher the risk reversal. Similarly, the underperformance of the Japanese stock market reflects a weaker economic outlook and puts downward pressure on the yen. However, as Japan is an export-based economy, an expected appreciation of the yen (higher the risk reversal) would have negative impact on its exports and thus reduce the stock market return. Therefore, the risk reversal and the Japanese market return could be negatively related. For the bond market variables, we use

[21] Collin-Dufresne et al. (2001), Cremers et al. (2008), and Zhang et al. (2009) use the VIX index as a measure of market-level volatility and find a strong relationship with firm-level credit spreads. Pan and Singleton (2008) view the VIX index as a measure of investors' risk aversion for the event risk in credit markets.

the term spreads between 10-year and 2-year yields of the US Treasuries (*USTerm*) and Japan government bond bonds (*JPTerm*). Collin-Dufresne et al. (2001) interpret the term spread (i.e., the slope of a yield curve) as a proxy for the overall state of an economy. An upward sloping yield curve indicates future economic growth, whereas a flattening yield curve reflects a poor economic prospect. Similar to the arguments for the stock market returns, we expect the term spread of the US and Japanese government bonds to be negatively related to the prices of dollar-put options and result in a higher risk reversal.

After incorporating all these control variables into the regression, it becomes

$$\begin{aligned}\Delta RR_t = {} & \alpha + \beta_1 \Delta CDS_{1,t-1} + \beta_2 \Delta CDS_{2,t-1} \\ & + \beta_3 \Delta (r_{USD} - r_{JPY})_t + \beta_4 \Delta R^2_{USD,t} + \beta_5 \Delta VIX_t + \beta_6 \Delta TED_t \\ & + \beta_7 \Delta SPX_t + \beta_8 \Delta USTerm_t + \beta_9 \Delta NIK_t + \beta_{10} \Delta JPTerm_t + v_t\end{aligned} \tag{5}$$

where v_t is the residual of the regression.[22]

We use different specifications of Eq. (5) to isolate the potential effects of multicollinearity. The regression analysis in Table 4 shows that the US sovereign CDS spread can explain the risk reversal after controlling the macro-financial factors during the period between September 2009 and August 2011, while Japan's sovereign CDS spread is not significant.[23] The explanatory power of the US CDS spread remains significant at the 5% confidence level and is not driven out by the set of additional control variables, given that its t-statistic increases from 1.81 to 2.11 and coefficient decreases from 0.023 to 0.019. The result supports the first hypothesis that the impact of sovereign credit risk on the risk reversal is mainly driven by the US but not Japan.

The regression can explain the 31% variation of the risk reversal. The differential between the US dollar and the yen interest rates show the expected positive sign and explain another 12% of the adjusted R-squared. While both the dollar and the yen interest rates were very low during the period, the US dollar LIBOR increased from 0.35% to 0.54% in early 2010 when the market expected the low interest rate environment in the US would come to an end soon.[24] The yen interest rate remained near zero in the period. This indicates that the risk reversal is very sensitive to the interest rate differential between the dollar and the yen. Consistent with the previous finding that the VIX index reflects global risk, it is significant with the expected positive sign and can explain an additional 7% of the risk reversal. This reflects that the yen was considered to be safer than the dollar by market participants during the sovereign debt crisis.

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22 As higher lags of the CDS information of the US and Japan are found to be statistically insignificant in the regression, they are excluded in the analysis.

23 The Japanese CDS spread is significant when it is the only variable in Eq. (5).

24 The market expected that the Federal Reserve would at some point need to begin to tighten monetary conditions to prevent the development of inflationary pressure. See B. S. Bernanke (2010), "Semiannual Monetary Policy Report to the Congress", February 24 2010, http://www.federalreserve.gov/monetarypolicy/mpr_20100224_part1.htm.

The Japanese stock market return and term spread are both significant with negative signs. Lower values of these two macro-financial condition factors of Japan may indicate expected weaker Japanese exports caused by an expected appreciation of the yen (higher the risk reversal). As they can explain another 9%, the macro-financial condition of Japan is an important determinant of the risk reversal. On the other hand, the US stock market return and term spread are not significant.[25] The change in the ex-post US dollar volatility and the TED spread are insignificant in the regression. This means that both the actual fluctuation of the dollar value and the funding liquidity constraint are not the determinants of the risk reversal. As a result, after controlling the interest rate differential, global risk and macro-financial variables, the regression results show that the US sovereign CDS spread is a significant determinant and thus support the second hypothesis that the US sovereign credit risk is a separable risk factor in driving the expectation of the dollar-yen exchange rate in the currency option market.

During the first sample period from December 2007 to September 2009 (i.e., before the sovereign debt crisis) when the global financial crisis deepened due to the Lehman default in September 2008, the results in Table 5 show that neither the US nor the Japanese sovereign CDS spreads were significant factors and did not have any effect on the risk reversal. This indicates that the currency option market was not concerned about the US sovereign risk, even though uncertainty about losses incurred in the US financial institutions prompted the Federal Reserve to supply funds to them during the period and the 5-year US CDS spread surged from the level of 10 bps to 100 bps in February 2009. Consistent with the extreme risk aversion during the period, the macro-financial factors including the VIX index and Japanese term spread are significant with the expected signs, while the other control variables are insignificant. The results in Tables 4 and 5 support the third hypothesis that the impact of the US sovereign credit risk on the expectation of the dollar-yen exchange rate in the currency option market is predominantly during the sovereign debt crisis from September 2009 to August 2011, but not before.

In summary, the empirical results support that the impact of sovereign credit risk on the risk reversal is driven by the US but not Japan, and is a separable risk factor in driving the market expectation of the dollar-yen exchange rate after controlling the macro-financial variables. The impact of the US sovereign credit risk is predominantly during the sovereign debt crisis from September 2009 to August 2011 but not the global financial crisis from November 2007 to September 2009. In pricing the out-of-the-money dollar-yen options, our estimation results support the notion that investors require a distinct type of risk premium associated with sovereign risk in a way different from other economic/financial factors suggested by Liu et al. (2005), Jurek (2009) and Fahri et al. (2009) during the sovereign debt crisis.

[25] The US stock market return and term spread are only significant in the absence of the VIX index, reflecting the collinearity between the macro-financial condition of the US and the risk appetite. The estimated correlations between the VIX and the US stock market return and between the VIX and the US term spread are -0.34 and -0.43 respectively, compared to the other variables' correlations being less than 0.15 in absolute terms.

4. Conclusion

The US and Japanese sovereign CDS spread varied in a wide range when the global financial crisis emerged in late 2007. This raises the question of any interconnectivity between the anticipated sovereign credit risk and the market expectation of the dollar-yen exchange rate in the crisis. This paper shows evidence of information flow from the sovereign CDS market to the dollar-yen currency option market during the sovereign debt crisis from September 2009 to August 2011 when concerns about sovereign credit risks in the developed economies were triggered. The empirical results imply that the impact of sovereign credit risk on the risk reversal is driven by the US, and is a separable risk factor in driving the market expectation of the dollar-yen exchange rate after controlling the macro-financial variables. While the Japanese sovereign CDS spread was higher than its US counterpart, its impact on the risk reversal was not significant.

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Table 1. Descriptive Statistics for 10-Delta Risk Reversals of Dollar-Yen Options and Sovereign CDS Spreads

Statistic	10-delta risk reversal (1-month)	10-delta risk reversal (3-month)	US sovereign CDS spread (5-year)	Japanese sovereign CDS spread (5-year)
(a) Sample period:11 December 2007 – 16 September 2009				
Mean	6.32	8.02	31.76	36.92
Median	4.73	6.53	26.00	37.34
Maximum	18.63	19.14	100.00	121.83
Minimum	1.80	4.39	5.80	6.00
Std. Dev.	3.92	3.72	24.22	25.28
Skewness	1.62	1.58	0.97	1.14
Kurtosis	4.72	4.28	3.03	3.88
Observations	463	463	463	463
Pairwise-correlation				
10-Delta risk reversal (1-month)	1.0000			
10-Delta risk reversal (3-month)	0.9728	1.0000		
US sovereign CDS spread (5-year)	0.1593	0.1217	1.0000	
Japanese sovereign CDS spread (5-year)	0.1768	0.1807	0.2353	1.0000
(b) Sample period: 17 September 2009 – 15 August 2011				
Mean	1.90	2.80	41.41	74.55
Median	1.69	2.64	41.62	73.39
Maximum	7.33	7.44	64.37	117.99
Minimum	0.00	1.02	20.00	38.17
Std. Dev.	1.26	1.26	8.27	14.54
Skewness	1.00	0.84	-0.55	-0.14
Kurtosis	4.43	3.38	3.64	2.76
Observations	498	498	498	498
Pairwise correlation				
10-delta risk reversal (1-month)	1.0000			
10-delta risk reversal (3-month)	0.9866	1.0000		
US sovereign CDS spread (5-year)	0.1304	0.1330	1.0000	
Japanese sovereign CDS spread (5-year)	0.1586	0.1591	0.1459	1.0000

Table 2. Cross Correlation and Granger Causality between Sovereign CDS Spreads and 3-Month 10-Delta Risk Reversals

	US sovereign CDS market		Japanese sovereign CDS market	
	Granger causality (F-test statistics)	Cross correlation (Chi-square test statistic)	Granger causality (F-test statistics)	Cross correlation (Chi-square test statistic)
Sample period: 11 December 2007 – 16 September 2009				
Δ(CDS spread) leads Δ(Risk reversal)	1.4722	6.9043	1.6680	7.5566
Δ(Risk reversal) leads Δ(CDS spread)	2.6554*	9.9417	4.1585*	20.7100*
Sample period: 17 September 2009 – 15 August 2011				
Δ(CDS spread) leads Δ(Risk reversal)	2.3236*	11.5096*	3.1256*	13.5223*
Δ(Risk reversal) leads Δ(CDS spread)	0.7065	4.0311	4.0584*	22.9513*

Notes: 1) * indicates significance at 5% level.

2) The table reports the F test statistics of the Granger causality test and the Chi-square test statistics of the cross correlation. The F test statistic checks whether the coefficients of one variable in the preceding periods (up to the fifth lag term) are jointly significant in the regression of the other in the current period. The Chi-square test checks whether the correlations between one variable in the preceding periods (up to the fifth lag term) and the other in the current period are jointly significant.

Table 3. Information Flow between Sovereign CDS and Currency Option Markets

	US sovereign CDS market		Japanese sovereign CDS market	
	Estimate	Chi-square test statistic	Estimate	Chi-square test statistic
Sample period:11 December 2007 – 16 September 2009				
$I = \sum_{k=1}^{n} \beta_k$ (flow from sovereign CDS to risk reversal)	-0.0319	1.1721	-0.0359	0.2841
$\tilde{I} = \sum_{k=1}^{n} \tilde{\beta}_k$ (flow from risk reversal to sovereign CDS)	0.1173	0.0257	0.7177	1.4432
Sample period: 17 September 2009 – 15 August 2011				
$I = \sum_{k=1}^{n} \beta_k$ (flow from sovereign CDS to risk reversal)	0.0289*	4.3232	0.0243*	4.9357
$\tilde{I} = \sum_{k=1}^{n} \tilde{\beta}_k$ (flow from risk reversal to sovereign CDS)	-0.6357	1.7223	0.0127	0.0003

Notes: 1) * indicates significance at 5% level.

2) The table reports the sum of coefficients of εs (up to the fifth lag term) in the equations (2) and (4). Its significance is checked by a Wald test which follows a chi-square distribution.

Table 4. Determinants of Changes in 3-Month 10-Delta Risk Reversals of Dollar-Yen Options from 17 September 2009 to 15 August 2011

Variable	Coeff	t-Stat		Coeff	t-Stat		Coeff	t-Stat		Coeff	t-Stat		Coeff	t-Stat	
Constant	-0.0076	-0.48		-0.0165	-1.17		-0.0178	-1.21		-0.0056	-0.32		-0.0076	-0.47	
US CDS spread (lag 1)	0.0187	2.11	**	0.0178	2.00	**	0.0215	2.23	**	0.0231	1.80	*	0.0231	1.81	*
Japanese CDS spread (lag 1)	0.0014	0.16		0.0095	1.10		0.0137	1.41		0.0145	1.45		0.0144	1.44	
Interest rate differential	29.4267	2.47	**	28.4781	2.38	**	31.4733	2.24	**						
Dollar squared return	-0.0504	-1.11								-0.0073	-0.17				
VIX index	0.0392	2.18	**	0.0488	2.85	**									
US Ted spread	0.0023	0.00													
Macro-financial condition															
US stock market return	-0.0005	-0.05													
US term spread	-0.2974	-0.76													
Japanese stock market return	-0.0323	-3.42	**												
Japanese term spread	-2.5932	-3.22	**												
Lags of dependent variable															
Risk reversal (lag 1)	-0.2265	-2.75	**	-0.1349	-1.44		-0.1689	-1.43		-0.1449	-0.99		-0.1443	-0.99	
Risk reversal (lag 2)	-0.0673	-1.15		0.0207	0.34		-0.0466	-0.67		-0.0295	-0.39		-0.0292	-0.38	
Risk reversal (lag 3)	-0.1405	-2.64	**	-0.0710	-1.36		-0.0786	-1.52		-0.0312	-0.59		-0.0312	-0.59	
Risk reversal (lag 4)	-0.1093	-2.11	**	-0.0354	-0.64		-0.0629	-1.21		-0.0298	-0.52		-0.0299	-0.52	
Risk reversal (lag 5)	-0.0837	-1.84	*	-0.0771	-1.66	*	-0.0935	-1.72	*	-0.0819	-1.39		-0.0831	-1.41	
R-squared	33%			23%			16%			4%			4%		
Adjusted R-squared	31%			22%			15%			3%			3%		
Durbin-Watson stat	1.92			2.03			1.85			2.01			2.01		
No. of observation	498			498			498			498			498		

Note: ** and * indicate significance at 5% and 10% levels respectively

Table 5. Determinants of Changes in 3-Month 10-Delta Risk Reversals of Dollar-Yen Options from 11 December 2007 to 16 September 2009

Variable	Coeff	t-Stat		Coeff	t-Stat		Coeff	t-Stat	Coeff	t-Stat	Coeff	t-Stat
Constant	-0.0333	-0.27		-0.0107	-0.09		-0.0083	-0.07	-0.0125	-0.14	0.0012	0.01
US CDS spread (lag 1)	0.0039	0.23		0.0144	0.82		0.0067	0.39	0.0103	0.71	0.0063	0.37
Japanese CDS spread (lag 1)	-0.0160	-1.18		-0.0109	-0.75		-0.0089	-0.61	-0.0004	-0.04	-0.0092	-0.63
Interest rate differential	-2.2095	-1.35		-1.3097	-0.88		-1.0686	-0.72				
Dollar squared return	0.0222	0.33							0.0271	0.47		
VIX index	0.0367	2.53	**	0.0517	4.06	**						
US Ted spread	0.7042	1.21										
Macro-financial condition												
US stock market return	-0.0129	-0.52										
US term spread	-0.2143	-0.26										
Japanese stock market return	-0.0127	-0.53										
Japanese term spread	-4.1839	-2.02	**									
Lags of dependent variable												
Risk reversal (lag 1)	0.0117	0.09		0.0758	0.71		0.0580	0.55	-0.0121	-0.15	0.0580	0.55
Risk reversal (lag 2)	0.0278	0.23		0.0898	0.87		0.0794	0.78	0.0386	0.49	0.0668	0.68
Risk reversal (lag 3)	-0.0690	-0.64		-0.0321	-0.35		-0.0383	-0.42	-0.0328	-0.44	-0.0388	-0.42
Risk reversal (lag 4)	-0.0550	-0.49		-0.0087	-0.09		0.0113	0.12	-0.0064	-0.08	0.0122	0.13
Risk reversal (lag 5)	0.0384	0.37		0.0314	0.32		0.0065	0.07	-0.0239	-0.31	0.0114	0.11
R-squared	24%			13%			3%		1%		1%	
Adjusted R-squared	21%			11%			1%		0%		0%	
Durbin-Watson stat	2.07			2.14			1.98		2.01		2.01	
No. of observation	463			463			463		463		463	

Note: ** and * indicate significance at 5% and 10% levels respectively

Figure 1. Sovereign CDS Spreads of US and Japan

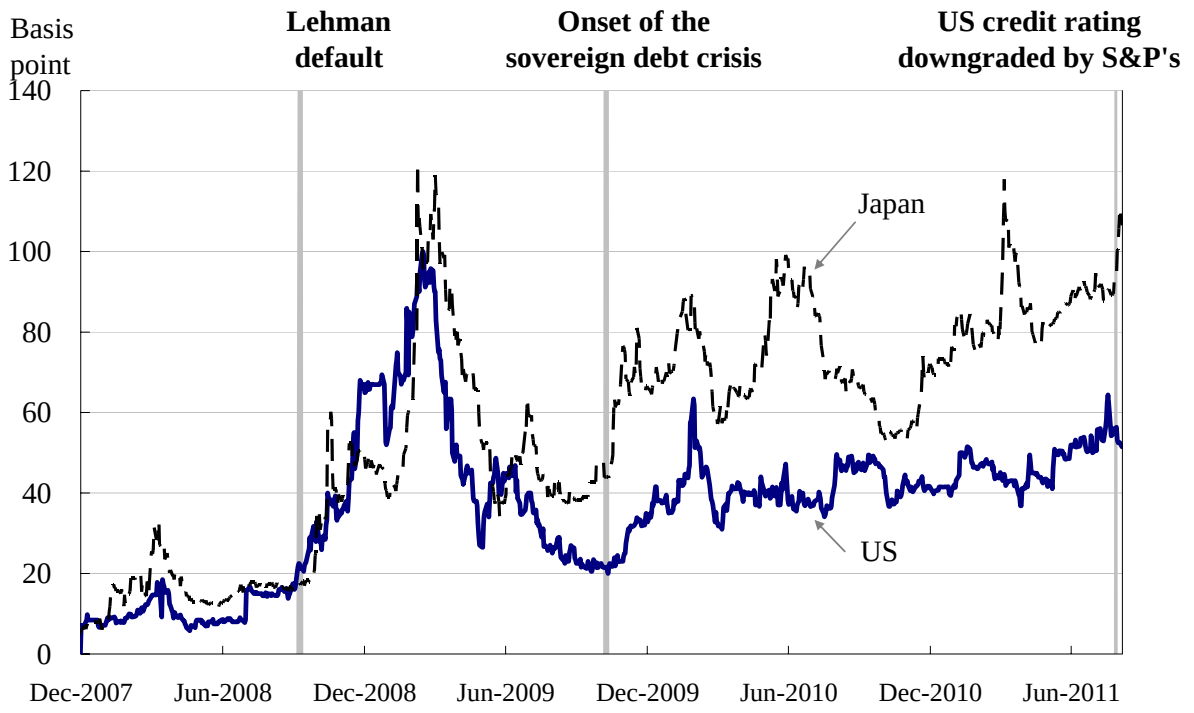
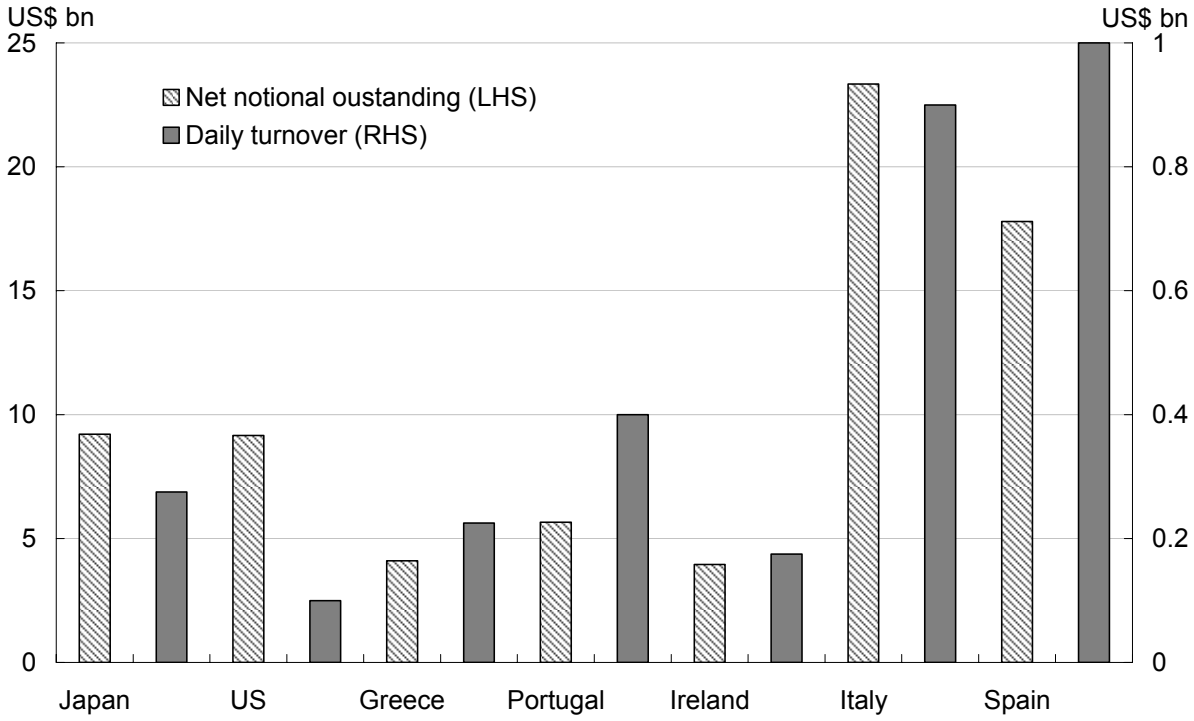


Figure 2. Net Notional Amounts Outstanding and Average Daily Turnover of Sovereign CDS Contracts of the Us, Japan and the Five Highly Indebted European Countries



Note: Net notional amounts outstanding are the aggregate net protection bought (or equivalently sold) across counterparts. The net notional outstanding shown is as at 21 October 2011 and the average amounts of daily turnover are the average during the period from December 2010 to March 2011. The data are from Depository Trust and Clearing Corporation. See www.dtcc.com.

Figure 3. 1-Month and 3-Month 10-Delta Risk Reversals and Spot Exchange Rate of Japanese Yen against US Dollar