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ABSTRACT

Euro at Risk: The Impact of Member Countries' Credit Risk on the Stability of the Common Currency*

In this paper, we empirically investigate the impact of the credit risk of Eurozone member countries on the stability of the Euro. In the absence of a common euro bond, euro-area credit risk is induced though the credit default swaps of the member countries. The stability of the euro is examined by decomposing dollar-euro exchange rate options into the moments of the risk-neutral distribution. We document that during the sovereign debt crisis changes in the creditworthiness of member countries have significant impact on the stability of the euro. In particular, an increase in member countries' credit risk results in an increase of volatility of the dollar-euro exchange rate along with soaring tail risk induced through the risk-neutral kurtosis. We find that member countries' credit risk is a major determinant of the euro crash risk as measured by the risk-neutral skewness. We propose a new indicator for currency stability by combining the risk-neutral moments into an aggregated risk measure and show that our results are robust to this change in measure. Noticeable is the fact that during the sovereign debt crisis, the creditworthiness of countries with vulnerable fiscal positions is the main risk-endangering factor of the euro-stability.

JEL Classification: G1
Keywords: credit default swaps, currency options, currency stability, european sovereign debt crisis and risk-neutral distribution

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1. Motivation

In view of the current sovereign debt crisis, understanding the dynamics of the credit risk of the euro-area countries proves urgent so as to prevent dire scenarios. At worst, the default of a major country would unleash the currency break-up, ravage the European banking system and ultimately engender a global economic slump. In this study, we view the Eurozone sovereign debt crisis through the twin lenses of sovereign credit swaps and currency option markets. In the absence of Eurobonds, we empirically examine the impact of the credit risk of member countries on the stability of the Euro.

The credit risk of a country can be measured through its sovereign credit default swap (CDS)[1]. Market prices of CDS spreads reflect the perception of financial markets about the economic-political stability of a country, and thus about the creditworthiness of a given sovereign. As shown by Pan and Singleton (2008), the changes in credit risk premiums of sovereign markets which translate into changes in sovereign CDS spreads, do not emanate from changes in fundamentals of the underlying economies. Rather, these variations mirror a change in the risk appetite of market participants in terms of credit exposure. A negative change in the creditworthiness of a sovereign inevitably translates into a depreciation of its currency along with soaring currency volatility. Furthermore, currency option prices are instruments which are capable of predicting the changes in the realized volatility of currency returns. Based on data from the Mexican and Brazilian Markets, Car and Wu (2007) establish a relationship between sovereign CDS spreads and currency return volatilities induced through implied-volatilities of currency options and risk reversals[2]. Their results indicate that the sovereign CDS spreads covary substantially with the risk reversals. In the same spirit, Hui and Fong (2011) report similar results while focusing on the interconnectivity between the US and Japan sovereign CDS markets and the currency option market characterized by risk reversals of options on the dollar-yen exchange rate. Compared to Japan, The US sovereign credit risk is shown to have a significant impact on

[1] A sovereign CDS contract provides protection against the non-payment of sovereign debt. Typically, it involves one counterparty agreeing to sell protection to another. The "protected" party pays a yearly premium known as the CDS spread in exchange for a guarantee that in the event of a default, the seller of protection will provide compensation.

[2] Risk reversal is the difference in volatility (delta) between similar out-of-the-money call and put options. A positive risk reversal implies that market participants are expecting an appreciation rather than a depreciation of the local currency. The risk reversal conveys information about the skewness of the exchange rate distribution.

the risk reversal. Therefore it is deemed to play a more significant role in the way markets form expectations on the dollar-yen exchange rate.

Turning to the European context, Hui and Chung (2011) document information transmission from the sovereign CDS market to the currency option market. Using implied volatilities of options on the dollar-euro exchange rate as a measure of crash risk, they conclude that the credit risk of the Eurozone is a distinct factor which determines the prices of the out-of-the-money euro put options prices. The recent Eurozone crisis is viewed from various angles by the literature. Azerti et.al (2011) and Alfonso et al. (2011) use the perspective of credit rating agencies and show that sovereign rating announcements have spillovers effect on the European financial markets. The first study examines the response of sovereign CDS spread, banking stock index, insurance stock index and country stock to these announcements, while the second focuses on the response of government yield spreads. Either way, news about downgrades is found to have significant spillover effects. However, the linkages with currency option markets are not considered. Another perspective is that of Calice et al. (2011) who analyse the Eurozone crisis by modelling liquidity in the sovereign CDS markets. They find evidence that the liquidity of CDS markets of struggling countries such as Greece, Portugal and Ireland has a substantial impact on sovereign debt spreads. An earlier strand of literature tackles the question of currency crash risk from a macro-economic angle and explains currency crash risk by economic fundamentals. It provides empirical evidence from developing countries of a relationship between macro-economic indicators and weak currencies. Countries with weak fundamentals are less likely to be able to defend their currencies against speculative attacks (Wolff (1987), Eichengreen et al. (1996); Frankel and Rose (1996); Kaminsky et al. (2003) are a few examples).

Our study also relates to a recent strand of literature which attempts to link currency crash risk to the distribution of exchange rate. Notwithstanding the sound models and explanations established by this strand, it does not take into account sovereign credit risk. Brunnermeier et al. (2009) detect negative skewness in the movements of exchange rates involving a low-level interest rate currency and a high-level one. This boils down to saying that carry trade strategies are exposed to crash risk. The authors argue that the skewness is triggered when such strategies take place in an abrupt manner reflecting lower risk appetite and higher liquidity constraints.

Currency risk with respect to Carry trade strategies are also examined in a work by Fahri et al. (2009).The main risk of these strategies emerges from the value of the exchange rate at the end. The authors propose an exchange model to distinguish between “disaster” and “Gaussian” premia in the currency option markets. The model entails a strong relationship between interest rates, changes in exchange rates and levels of risk reversals. The main empirical implication indicates that disaster premium explains 25% of carry trades returns. In others words, crash risk drives currency returns considerably. Jylha and Suominen (2010) test the prediction of a two country general-equilibrium model and find empirical evidence that hedge fund investment strategy predicted referred to as a “risk adjusted carry trade strategy”, accounts for more than 16% of a broad hedge fund index returns .Other papers, which find a similar result by analyzing crash risk from the perspective of currency options include the work of Jurek (2009) and Burnside et al. (2011).

Moreover, our study is related to the literature examining the linkage between corporate CDS and stock option markets and the information transmission inherent to these markets. Examples include work by Acharya and Johnson (2007), which presents empirical evidence on the existence of information transmission from the corporate CDS to the stock market. This phenomenon is detected for firms which were subject or are likely to be subject to negative credit news and which maintain strong ties with banks. The analysis of the relation between CDS spreads and implied-volatilities in the work of Cao et al. (2010) shows that the information embedded in the implied volatilities of deep out of the money put options is able to explain the variations in CDS spreads. The skew of the implied volatilities is also computed so as to examine its effect on CDS spreads. Important to note is the fact that this implied volatility is related to the negative tail of the risk neutral probability. Besides, the information embedded in it reflects both future volatility and risk premium.

In an effort to shed more light on the current sovereign debt crisis, our study proposes the use of a sound and state-to-the art measure to assess the stability of the Euro. Based on the framework of Bakshi et al. (2003), the stability of the euro is examined by decomposing dollar-euro[3] exchange rate options into the moments of the risk-neutral distribution. The method is partly

[3] The quotation ‘dollar-euro’ refers to the amount of dollars needed to obtain one unit of euro.

used in the recent empirical option pricing literature (see e.g. Bams et al. (2009) and Neumann and Skiadopoulos (2012)). In particular, we compute model-free risk-neutral volatility, skewness and kurtosis measures from the cross-section of currency option prices, which allow us to evaluate the stability of the euro. Skewness is typically interpreted as the euro crash risk, while risk-neutral kurtosis as the tail risk of the exchange rate distribution. The first measure gives an indication in which direction market participants are expecting the dollar-euro exchange rate to move. A negative skewness reflects concerns about a depreciation of the euro, which translates into the willingness of investors to pay a higher risk premium for put options relative to call options in order to obtain protection for the potential drop in value. Tail risk refers to extreme events whose probability is low but whose impact on prices is large should they materialize. In particular, during the European sovereign debt crisis, we expect that possible concerns about the stability of the euro should be reflected in a negative skewness of the dollar-euro exchange rate options. The focus of this study is to examine the impact of the credit risk of Eurozone member countries on the stability of the Euro.

We document that changes in the creditworthiness of a member country on one day have a significant impact on the stability of the euro the following day. On the one hand, an increase in member countries' credit risk results in an increase of the volatility of the dollar-euro exchange rate along with soaring tail risk induced through the risk-neutral kurtosis. On the other, we find that member countries' credit risk is a major determinant of the euro crash risk as measured by the risk-neutral skewness. Based on those results, we propose a new indicator for currency stability by combining the risk-neutral moments into an aggregated risk measure and show that our results are robust to this change in measure. Noticeable is the fact the creditworthiness of countries with vulnerable fiscal positions is the main, but not the only risk-endangering factor of the euro-stability. While the creditworthiness of the latter countries has a significant impact on the skewness measure (i.e. crash risk) and the stability indicators, healthier countries equally drive the relationship between the creditworthiness and the volatility as well as the kurtosis (i.e. tail risk) of the risk-neutral distribution.

The remainder of this paper is structured as follows: The next section describes the data and presents some summary statistics. Then, the methodologies with respect to the option pricing aspects and the regression analyses are explained. Subsequently, the empirical results are outlined and discussed. The last section contains concluding remarks.

2. Data & Summary Statistics

Data

We collect data on daily 5-year sovereign CDS spreads for 11 countries: Belgium, France, Germany, Netherlands, Austria, Finland, Greece, Spain, Italy, Ireland, Portugal. The source used to obtain the sovereign CDS quotes is Bloomberg's CMAT portal. In addition, we obtain a complete cross-section of daily over-the-counter dollar/euro option prices together with the underlying spot exchange rates, as well as interest rates for Europe and the US through Thomson Reuters' Tick History system. Our data sample covers the period from September 10th 2007 to January 31st 2012[4]. Our data underwent a rigorous cleaning process in order to obtain the final dataset.

Currency option prices

We obtain OTC European type dollar/euro option prices quoted in implied volatilities at fixed maturities. We used the 1, 3, 6 and 9 months maturity options, because they are the most frequently traded ones. The option quotes are in terms of implied volatilities for particular put and call deltas categories, which is a common industry practice. The different delta categories cover the complete moneyness range of the currency options, e.g out-of-the-money calls and puts at 10-15-20-25-30-35-40-45-delta and at-the-money-options at 50-delta. Using the available delta- and maturity categories of all option contracts, on each day, we fit a functional form to the observed implied volatilities of the options, which allows us to obtain implied volatilities for every possible delta-maturity combination. That allows us to calculate call and put option prices through the Black-Scholes model. Thereafter, on a daily frequency, we are able to derive the moments of the risk-neutral distribution of the dollar-euro exchange rate options.

Sovereign CDS spread

[4] However, we had to reduce the sample period for the regression analysis due to lack of reliable sovereign CDS data for certain countries before September 5th 2008. Nonetheless, our sample period still covers the subprime and the sovereign crises.

The sovereign credit default swaps, expressed in basis points, are traded at various maturities of up to 30 years. We retrieve the 5-years maturity quotes for the 11 euro-area countries in the analysis since they are the most liquid.

Summary Statistics

Table 1 portrays the summary statistics of individual countries' CDS spreads. We report summary statistics for the subprime crisis period and the sovereign debt crisis period separately. In line with previous research (Hui and Chung (2011)), we assume that October 14th 2009 was the onset of the European sovereign debt crisis. Therefore, the subprime crisis covers the period from September 5th 2008 until October 13th 2009. The period starting on October 14th 2009 and ending at January 31st 2012 represents the sovereign debt crisis period.

[Table 1]

Panel A shows the overall statistics for the full sample and reveals the obvious difference in the creditworthiness of the Euro member countries. Based on the CDS data, one might want to characterize certain countries as healthy countries with stable economic conditions and vulnerable countries with fragile economic conditions. Following this logic, France, Germany, Netherlands, Finland and Austria would belong to the group of healthy countries. In contrast, Ireland, Spain, Portugal, Greece and Italy would belong to the group vulnerable country. We leave Belgium due to its political instability unclassified, while its CDS spread would suggest that it could be included in one of the groups. Panel B and Panel C allow us to compare the CDS spreads during the subprime crisis period and during the sovereign debt crisis. The summary statistics reveal substantial differences in the CDS spreads across countries. These differences are particularly pronounced during the sovereign debt crisis. While the average CDS spreads for the healthy countries shows only a slight increase during the subprime crisis, the increase in spreads was substantial for the vulnerable countries. As shown by panel C, the average value is 39bps for Finland and 1359 bps for Greece.

Tables 2 and 3 report summary statistics of the dollar-euro option prices quoted in terms of 10-delta and 25-delta implied-volatilities of calls and puts. The at-the-money options statistics are only reported once together with the put statistics. Summary statistics are presented for four different maturities. The statistics are computed over a sample period covering the subprime- and sovereign debt crisis period, ranging from September 5th 2008 until January 31st 2012. Overall, the implied volatilities for calls and puts increase with maturity and they are on average higher during the sub-prime crisis.

[Table 2 and 3]

Figure 3 shows the dollar-euro option smile on February 14th 2012 for maturities of up to 9 months. The graph nicely characterizes the extreme shape of the smile, which characterizes the European sovereign debt crisis period. The smirk-type shape, typically observed for equity options, refers to the negative skewness in the risk-neutral distribution of the dollar-euro exchange rate and, therefore, proxies the crash risk of the euro.

[Figure 3]

3. Methodology

It is industry practice to quote currency options in terms of implied volatilities at particular deltas. The Black-Scholes deltas of European-style call and put options are given by

$$\text{delta}_C = e^{-qT} N\left(\frac{\ln(Se^{(r-q)T} / K) + 0.5\sigma^2 T}{\sigma\sqrt{T}} \right) \quad (1)$$

$$\text{delta}_P = -e^{-qT} \left(1 - N\left(\frac{\ln(Se^{(r-q)T} / K) + 0.5\sigma^2 T}{\sigma\sqrt{T}} \right) \right) \quad (2)$$

where S is the dollar-euro exchange rate, K is the exercise, σ is the implied volatility of the option, r and q are the US and European risk-free interest rates corresponding to the time to maturity (T) of the option and N(.) is the cumulative normal distribution.

Estimating the implied volatility surface

For the empirical analysis, we first use a modification of the prominent ad-hoc Black-Scholes model of Dumas, Fleming and Whaley (1998) to estimate the implied volatility surface of our currency options. We use all available information content in currency option prices for different moneyness (deltas) and different maturities. The aim is to construct a time series of standardized measures (e.g. risk neutral volatility, skewness and kurtosis) that characterize the cross-section of prices and can be compared over time. Rather than averaging the two contracts that are closest to at-the-money or closest to one month maturity, we fit the modified ad-hoc Black-Scholes model to all option contracts on a given day and subsequently obtain the desired functional form of the implied volatility surface. This strategy successfully eliminates some of the noise from the data (see Christoffersen et al. (2010)). We allow each option to have its own Black-Scholes implied volatility depending on the options delta and time to maturity T. We use the following functional form for the options implied volatility:

$$IV_{i,j} = \alpha_0 + \alpha_1 \text{delta}_{C\,i,j} + \alpha_2 \text{delta}_{C\,i,j}^{2} + \alpha_3 T_j + \alpha_4 T_j^2 + \alpha_5 \text{delta}_{C\,i,j} T_j\,, \tag{3}$$

where IV_{ij} denotes the observed implied volatility and $\text{delta}_{C,i,j}$, the delta of a call option for the i-th moneyness and j-th maturity, defined in Equation (1)[5]. T_j denotes the time to maturity of an option for the j-th maturity. It is common practice to estimate the parameters using standard OLS. For every call option delta (or put option delta) and maturity, we can compute the implied volatility and derive option prices using the Black-Scholes model. For example, the implied volatility for an at-the-money short term call option with three month maturity can be derived by setting delta equal to 0.5 and time to maturity T equal to 3/12.

Calculating the moments of the risk-neutral distribution

Having characterized the implied volatility surface of the dollar-euro exchange rate options, we calibrate the moments of the resulting risk-neutral distribution. Bakshi et al. (2003) derive a model-free measure of risk-neutral variance, skewness and kurtosis based on all options over the complete moneyness range for a particular time to maturity T.

Variance, skewness and kurtosis of the T-month risk-neutral distribution can be computed by

[5] For put options, we use the corresponding call delta in the implied volatility regression.

$$Variance_t(T) = e^{rT} V_t(T) - \mu^2$$

(4)

$$Skewness_t(T) = \frac{e^{rT} W_t(T) - 3\mu_t(T) e^{rT} V_t(T) + 2\mu_t(T)^3}{\left[e^{rT} V_t(T) - \mu_t(T)^2\right]^{\frac{3}{2}}}$$

$$Kurtosis_t(T) = \frac{e^{rT} X_t(T) - 4\mu_t(T) e^{rT} W_t(T) + 6 e^{rT} \mu_t(T)^2 V_t(T) - 3\mu_t(T)^4}{\left[e^{rT} V_t(T) - \mu_t(T)^2\right]^2}$$

(5)

where

$$\mu_t(T) = e^{rT} - 1 - \frac{e^{rT}}{2} V_t(T) - \frac{e^{rT}}{6} W_t(T) - \frac{e^{rT}}{24} X_t(T)$$

$$\mathrm{V}_t(T) = \int_{S_t^{-qT}}^{\infty} \frac{2(1 - \ln(K / S_t^{-qT}))}{K^2} c_t(T, K) dK + \int_0^{S_t^{-qT}} \frac{2(1 + \ln(S_t^{-qT} / K))}{K^2} p_t(T, K) dK$$

$$\mathrm{W}_t(T) = \int_{S_t^{-qT}}^{\infty} \frac{6 \ln(K / S_t^{-qT})) - 3\left(\ln(K / S_t^{-qT})\right)^2}{K^2} c_t(T, K) dK$$

$$- \int_0^{S_t^{-qT}} \frac{6 \ln(S_t^{-qT} / K)) - 3\left(\ln(S_t^{-qT} / K)\right)^2}{K^2} p_t(T, K) dK$$

$$\mathrm{X}_t(T) = \int_{S_t^{-qT}}^{\infty} \frac{12 \ln(K / S_t^{-qT})) - 4\left(\ln(K / S_t^{-qT})\right)^3}{K^2} c_t(T, K) dK$$

$$+ \int_0^{S_t^{-qT}} \frac{12 \ln(S_t^{-qT} / K)) - 4\left(\ln(S_t^{-qT} / K)\right)^3}{K^2} p_t(T, K) dK$$ and

The parameters correspond to the ones used in Equation (1) and (2). c and p refer to call and put prices. Again, rather than averaging the observed implied volatilities of all contracts that are closest to one particular maturity (e.g. 3 month), we derive the Bakshi et al. (2003) risk-neutral moments using the estimated implied volatility surface and the corresponding call and put prices. In the empirical analysis, we focus on the 3 months horizon and calculate the moments of the 3-months risk-neutral distribution.

Regression analysis

The first step in our analysis is to regress daily changes in credit default spreads of country i on contemporaneous and lagged changes in the various moments that we use to characterize the risk-neutral distribution as well as on lagged changes in credit default spreads in order to extract the residual component, hence, we estimate the following equations[6]

$$\Delta CDS_{i,t} = \omega^{Vol}{}_i + \sum_{k=0}^{5} \upsilon^{Vol}{}_{i,k} \Delta Vol_{t-k} + \sum_{k=1}^{5} \psi^{Vol}{}_{i,k} \Delta CDS_{i,t-k} + \varepsilon_{i,t}^{CDS,Vol} \tag{6a}$$

$$\Delta CDS_{i,t} = \omega^{Skew}{}_i + \sum_{k=0}^{5} \upsilon^{Skew}{}_{i,k} \Delta Skew_{t-k} + \sum_{k=1}^{5} \psi^{Skew}{}_{i,k} \Delta CDS_{i,t-k} + \varepsilon_{i,t}^{CDS,Skew} \tag{6b}$$

$$\Delta CDS_{i,t} = \omega^{Kurt}{}_i + \sum_{k=0}^{5} \upsilon^{Kurt}{}_{i,k} \Delta Kurt_{t-k} + \sum_{k=1}^{5} \psi^{Kurt}{}_{i,k} \Delta CDS_{i,t-k} + \varepsilon_{i,t}^{CDS,Kurt} \tag{6c}$$

We do this for up to five lags to absorb any contemporaneous information transmission and any lagged information transmission. In this way, we are able to identify the information arriving in the CDS market, which is not based on information that has been revealed in the dollar-euro options market. The resulting residuals ε_t can be interpreted as innovations in the CDS market relative to the risk-neutral moments that characterize the market conditions in the currency options market.

Subsequently, for each country i, we run a regression of changes in the moments of the risk-neutral distributions on lagged innovations in the CDS market and lagged changes in the variable itself, hence, we estimate

$$\Delta Vol_t = \tau^{Vol}{}_i + \sum_{k=1}^{5} \lambda^{Vol}{}_{i,k} \varepsilon_{i,t-k}^{CDS,Vol} + \sum_{k=1}^{5} \theta^{Vol}{}_{i,k} \Delta Vol_{t-k} + \mu^{Vol}{}_{i,t} \tag{7a}$$

$$\Delta Skew_t = \tau^{Skew}{}_i + \sum_{k=1}^{5} \lambda^{Skew}{}_{i,k} \varepsilon_{i,t-k}^{CDS,Skew} + \sum_{k=1}^{5} \theta^{Skew}{}_{i,k} \Delta Skew_{t-k} + \mu^{Skew}{}_{i,t} \tag{7b}$$

$$\Delta Kurt_t = \tau^{Skew}{}_i + \sum_{k=1}^{5} \lambda^{Kurt}{}_{i,k} \varepsilon_{i,t-k}^{CDS,Kurt} + \sum_{k=1}^{5} \theta^{Skew}{}_{i,k} \Delta Kurt_{t-k} + \mu^{Skew}{}_{i,t} \tag{7c}$$

[6] We use log-changes for CDSs and simple changes for the other variables, which allow us to compare the results across countries.

For each of the risk-neutral moments, we examine $\beta^{Vol}{}_i = \sum_{k=1}^{5} \lambda^{Vol}{}_{i,k}$, $\beta^{Skew}{}_i = \sum_{k=1}^{5} \lambda^{Skew}{}_{i,k}$ and $\beta^{Kurt}{}_i = \sum_{k=1}^{5} \lambda^{Kurt}{}_{i,k}$ as measures of impact of countries' i credit risk on the risk-neutral moments of the dollar-euro exchange rate and, therefore, on the stability of the euro. A motivation and detailed discussion of the usefulness of this approach for testing transmission effects can be found in Acharya and Johnson (2007) and Berndt and Ostrovnaya (2008).

4. Empirical results

Figure 1 shows the annualized volatility of the 3-month risk–neutral distribution together with the dollar-euro exchange rate over the period from September 10th 2007 to January 31st 2012. Figure 2 shows the daily risk-neutral skewness and kurtosis of 3 month options calculated according to Bakshi et al. (2003). Interestingly, during the subprime crisis, the skewness is mainly positive and turns negative during the subsequent European sovereign debt crisis, with a turning point in October 2009, typically deemed to be the start of the sovereign debt crisis. Kurtosis was much higher and more volatile during the subprime crisis and reaches its peak in December 2008.

[Figure 1 and 2]

Clearly, our risk neutral skewness measure is able to distinguish between turbulent times. During the subprime crisis, our measure is positive reflecting a possible depreciation (crash risk) of the Dollar. Towards mid-October 2009, the skewness measure turns negative, suggesting a change in the market expectations of the euro vis-à-vis the dollar. That is, markets expect the euro to depreciate, which translates into buying put options[7] of the dollar-euro exchange rate. The lower kurtosis exhibited during the sovereign debt crisis is synonymous to "thinner" tails of the risk-neutral distribution of the dollar-euro exchange rate. Therefore, the tail risk of the two currencies

[7] Garleanu, Pedersen and Poteshman (RFS 2009), model demand-pressure effects on option prices. They also empirically show that demand helps explain the overall expensiveness and skew patterns of index options. In view of our analysis we could argue that investors form expectations about exchange rate movements based on the CDS spreads they observed. Hence, a high level of spreads implying a deteriorating creditworthiness spurs demand for protection (i.e. put options) against the potential drop in the dollar-euro exchange rate (i.e a weaker euro) and ultimately leads to the negative skew.

seems to be priced in the US. The subprime crisis starting with the burst of the housing bubble in the US had a major impact on the US economy. Figure 2 shows that during the subprime crisis, not only the volatility of the dollar-euro exchange rate substantially increased, but the kurtosis of the risk-neutral distribution, our proxy for tail risk, increased as well. However, during the sovereign debt crisis period the volatility increased, but the tail risk of the two currencies is relatively stable at a low level.

[Table 4]

Summary statistics of the dollar-euro exchange rate and the risk-neutral moments are displayed in Table 4. The skewness measure is positive over the sub-prime crisis (0.47) but becomes negative during the sovereign debt crisis (-0.37) reflecting concerns of market participants about the stability of the euro. With respect to the kurtosis measure, the lower kurtosis exhibited during the sovereign debt crisis (5 versus 8 in the prior period) is synonymous to “thinner” tails of the risk-neutral distribution of the dollar-euro exchange rate and, therefore, lower tail risk.

Table 5 summaries our regression analysis results. The reported betas refer to the sum of regression coefficients based on equations (7a) – (7c) and can be interpreted as measures of impact of countries’ i credit risk on the risk-neutral moments of the dollar-euro exchange rate and, therefore, on the stability of the euro. For the complete sample period, the results suggest that member countries creditworthiness affects the volatility of the dollar-euro exchange rate. An increase in the CDS spreads, indicating worsening credit conditions, has a positive impact on the volatility of the exchange rate. However, the results for skewness and kurtosis are typically insignificant. Once we split the period into a subprime crisis period and a sovereign debt crisis period, we observe significant differences over time. Looking at the subprime crisis period, our estimates have no statistical significance. The interpretation is that the credit risk of the euro-area member countries as measured by their CDS spreads does not affect the stability of the euro induced through the skewness (Skew) and kurtosis (Kurt) of the risk-neutral distribution of the dollar-euro exchange rate together with the risk-neutral volatility. In contrast, the results during the sovereign debt crisis period are quite pronounced. An increase in member countries’ credit risk results in an increased risk-neutral volatility of the dollar-euro exchange rate along with soaring tail risk induced through the risk-neutral kurtosis. Furthermore, the impact for healthy countries is significantly not different to the impact for vulnerable countries. As a result, both vulnerable and healthy countries have an impact on the stability of the euro in the way that higher levels of volatility are accompanied by lower levels of the exchange rate , and in turn, a weaker euro.

Furthermore, we find that member countries' credit risk is a major determinant of the euro crash risk as measured by the risk-neutral skewness. Overall, the relationship is negative, suggesting that an increase in countries' credit risk has a negative impact on the stability of the euro.

[Table 5]

With respect to the skewness measure, we find statistical significance only among countries belonging to the "vulnerable" group, namely: Ireland, Spain, Portugal and Italy. These coefficients are substantially negative, which entails that the struggling countries drive the euro crash risk. It can be shown that the betas for the healthy countries and the ones of the vulnerable countries are significantly different form each other at the 1% level. Contrary to what one would expect, the creditworthiness of Greece does not seem to play a looming role in the stability of the common currency. This reflects the fact that currency option markets do not perceive the credit risk of Greece as a major determinant or risk factor for the stability of the euro.

It is interesting to confront these findings with figures published by the Bank for International Settlements (BIS). On a regular basis BIS publishes cross-border claims of BIS reporting European banks. The Eurozone member countries are interlinked throughout the foreign claims their national banks hold. Given this exposure, a default of one country would cause a spread of the crisis to the rest of the member countries. The speed and magnitude of those contagious effects depend on the amount of debt the defaulting country owes to the rest of Eurozone countries as well the way it is connected to their respective banks. Put another way, the higher the foreign exposure of a given country to the banks of other Eurozone countries, the stronger the potential contagion effects. Looking at the BIS figures for the third quarter of 2009, the onset of the sovereign debt crisis, the data suggest that other vulnerable countries like Ireland, Portugal, Spain and Italy account for nearly 16% of foreign claims in European banks[8], while Greece only accounts for a bit more than 1%. Interestingly, we find that the creditworthiness of countries like Ireland, Portugal, Spain and Italy have an impact on the stability of the euro, while the results for Greece are insignificant. Additionally, Figure 4 illustrates the Eurozone debt structure as of the end of June 2011.

[Figure 4]

Each cycle represents the foreign exposure of a given Eurozone country to other member countries as well as its exposure to major economies. The figure shows how a country would influence the rest in the event of a default. The countries of interest are: Greece, Spain, Portugal, Italy and Ireland. With 2tn euro of gross foreign debt, Italy has the highest exposure towards national banks of the Eurozone countries, and those of the U.S, Japan, and the UK. Spain comes second with 1.9tn, followed by Ireland 1.7tn and finally Portugal and Greece at the same indebtedness level of 0.4 tn. Given these amounts and the interlinkages of each country with national banks of the other countries, the creditworthiness of Italy, Ireland and Spain seem to be the main sources of worry regarding the common currency, which is in line with our empirical results. French and German banks together hold 429bn, 243.7bn, 105,8 bn of Italian, of Spanish and Irish debt respectively, whereas they only hold 57.3 of Greek claims. This lends further credence to our results which do not display significance for Greece. In the case of default, France and Germany would be in position to absorb the shock more easily than if Italy, Spain or Ireland were to default. Furthermore, while Portugal and Greece have similar levels of debt, Portugal proves more unsettling because it is more intimately linked to another struggling country like Spain.

A new indicator for currency stability

[8] European banks refer to domestically owned banks of Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, and the UK.

In the following, we combine the three risk neutral moments into one aggregated risk indicator that characterizes the complete risk-neutral distribution. This allows us to derive one single market-based indicator that measures currency stability from the cross-section of exchange rate options. During the sovereign debt crisis period, this indicator would measure the euro instability. However, the comovements of these three moments are supposed to have a nonlinear impact on the risk-neutral distribution as a whole. Some popular risk measures in risk management, such as Value at Risk (VaR) and Expected Shortfall (ES) constructed from this risk-neutral distribution are expected to be a good indicator of the euro stability. The Gram-Charlier and Cornish-Fisher expansions are tools often used to compute VaR and ES in the context of skewed and leptokurtic return distributions. These approximations use the higher moments of the unknown target distribution to compute an approximate distribution and quantile functions. Simonato (2011) compares these methods with the Johnson System of distributions which also uses the moments as main inputs but is capable of accommodating all possible skewness and kurtosis. In this study, we consider an alternative approach based on the Pearson System (Pearson (1895)), which can be used to model a wide scale of distributions with various skewness and kurtosis. The Pearson System is a family of probability density distributions which includes a unique distribution corresponding to every valid combination of the moments of a distribution. It is possible to find the distribution in the Pearson system that precisely matches the moments of the risk-neutral distribution and to generate a random sample. We calculate the VaR and ES for both lower tail and upper tail at the 1%-quantile from the generated random samples. We construct two euro stability indicators by relating the upper tail of the risk-neutral distribution to the lower tail, e.g. the absolute VaR of the upper 1%-quantile divided by the absolute VaR of the lower 1%-quantile. Clearly, these indicators accurately summarize the imbalances of extreme values of the risk-neutral distribution overall and can be considered to reflect currency stability. For example, a ratio below one indicates a fatter left tail of the distribution compared to the right tail and, therefore, suggests euro instability. Figure 5 shows the stability indicators for the complete period.

[Figure 5]

We replicate the 2-step regression analysis outlined in Equations (6) and (7) by replacing e.g. the skewness measure by the different stability indicators. The resulting betas are shown in Table 6. VaR ratio refers to the indicator based on the Value-at-Risks measure and ES ratio refers to the indicator based on the expected shortfall measure.

[Table 6]

The results suggest that our previous findings are robust to a change of measure for euro stability. Most of the coefficients are insignificant except the ones for the sovereign debt crisis sub sample. During that period, all coefficients are substantially negative, which entails that member countries credit risk have a negative impact on the stability of the euro. But again, during the sovereign debt crisis period the struggling countries drive the instability of the common currency. It can be shown that the betas for the healthy countries and the ones of the vulnerable countries are significantly different form each other at the 5% level for both indicators. In line with previous findings and contrary to what one would expect, the creditworthiness of Greece does not seem to affect the stability of the common currency significantly.

5. Conclusions

In this paper, the recent Eurozone sovereign debt crisis is viewed through the twin lenses of sovereign credit swaps and currency option markets. We empirically investigate the impact of the credit risk of Eurozone member countries on the stability of the Euro. The credit risk of a country can be measured through its sovereign credit default swap (CDS). Market prices of CDS spreads reflect the perception of financial markets about the economic-political stability of a country, and thus about the creditworthiness of a given sovereign. The stability of the euro is examined by decomposing dollar-euro exchange rate options into the moments of the risk-neutral distribution. We document that changes in the creditworthiness of a member country on one day have a significant impact on the stability of the euro the following day. On the one hand, an increase in member countries' credit risk results in an increase of the volatility of the dollar-euro exchange rate along with soaring tail risk induced through the risk-neutral kurtosis. On the other hand, we find that member countries' credit risk is a major determinant of the euro crash risk as measured by the risk-neutral skewness. We propose a new indicator for currency stability by combining the risk-neutral moments into an aggregated risk measure and show that our results are robust to this change in measure. In line with previous research, these findings apply to the period of the sovereign debt crisis but not necessarily to the subprime crisis period. Noticeable is the fact the creditworthiness of countries with vulnerable fiscal positions is the main, but not the only risk-endangering factor of the euro-stability. While the creditworthiness of the latter countries has a significant impact on the skewness measure (i.e crash risk) and the stability indicators, healthier countries equally drive the relationship between the creditworthiness and the kurtosis (i.e tail risk). As one would expect, Ireland, Portugal, Spain and Italy play a prominent role. However, this does not seem to be the case for Greece, which can be partly explained by the only marginal foreign exposure of European banks to Greece.

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Figure 1.
Dollar-euro exchange rate and annualized volatility of the 3-months risk-neutral distribution of options on the dollar-euro exchange rate

Figure 2
Skewness and kurtosis of the 3-months risk-neutral distribution of options on the dollar-euro exchange rate

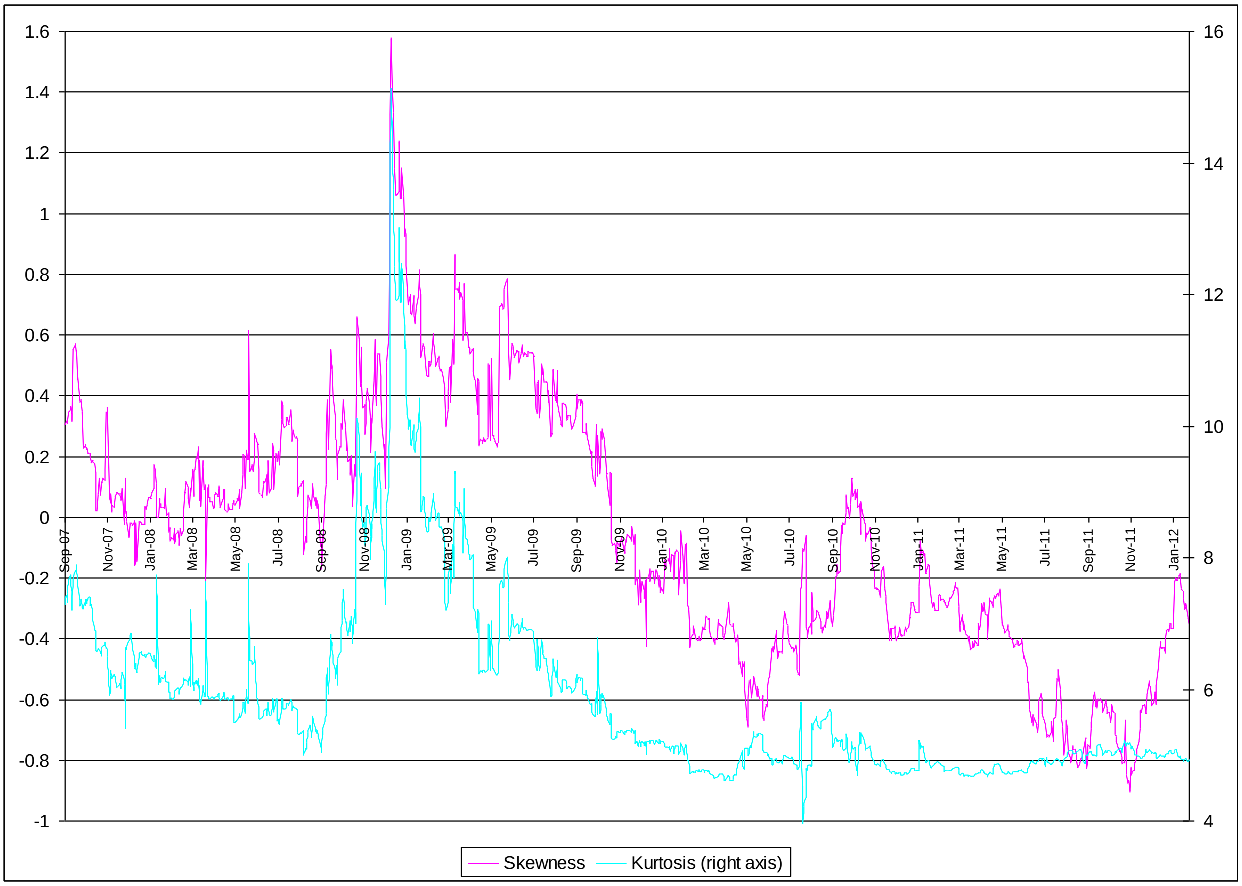

Figure 3
Dollar-euro option smile on February 14th 2012 for various maturities (Source: www.fxoptions.com website)

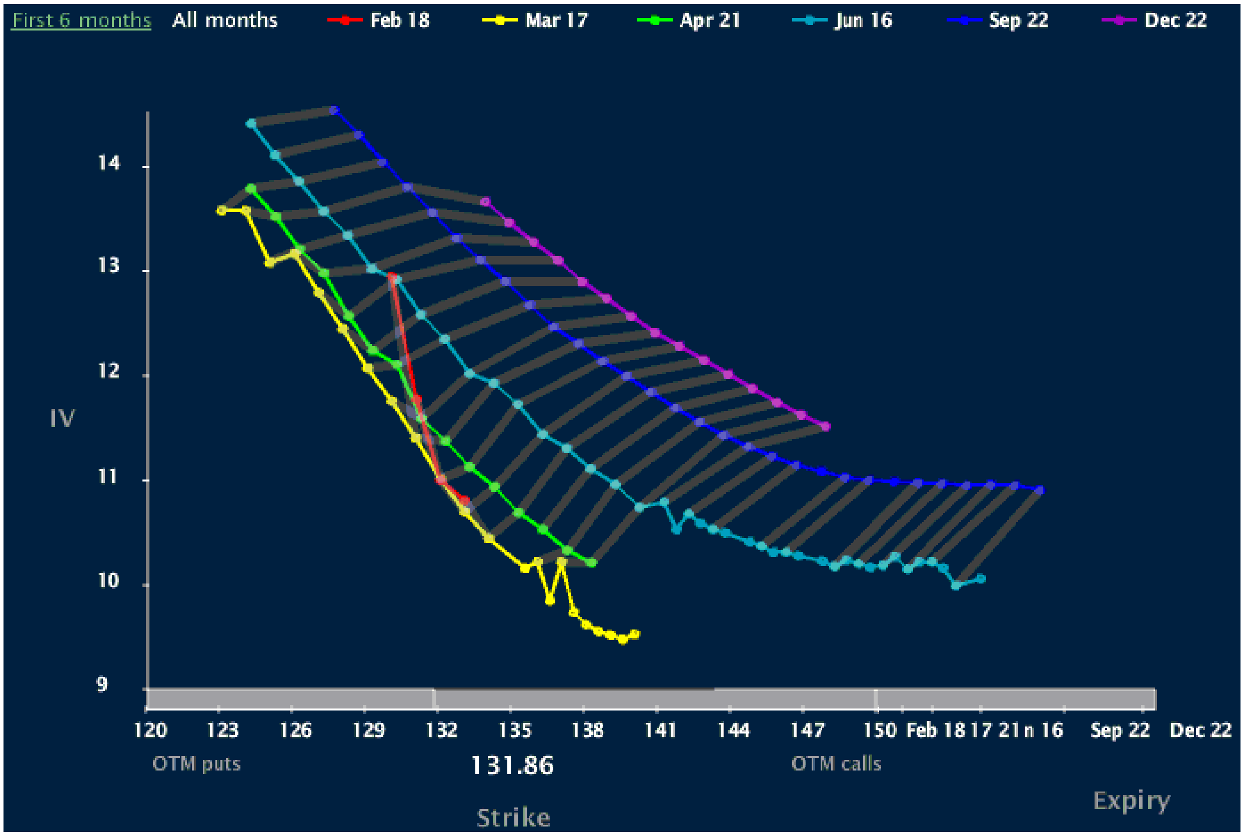

Figure 4. BBC Eurozone debt web: Who owes what to whom?

The circles below summarize data from the Bank for International Settlements and show the gross external, or foreign, debt of some of the main players in the eurozone as well as other big world economies. The arrows point from the debtor to the creditor and are proportional to the money owed as of the end of June 2011. The exposures, represented by the proportional arrows, shows what banks in one country are owed by debtors - both government and private - in another country. (Source: BBC website, http://www.bbc.co.uk/news/business-15748696)

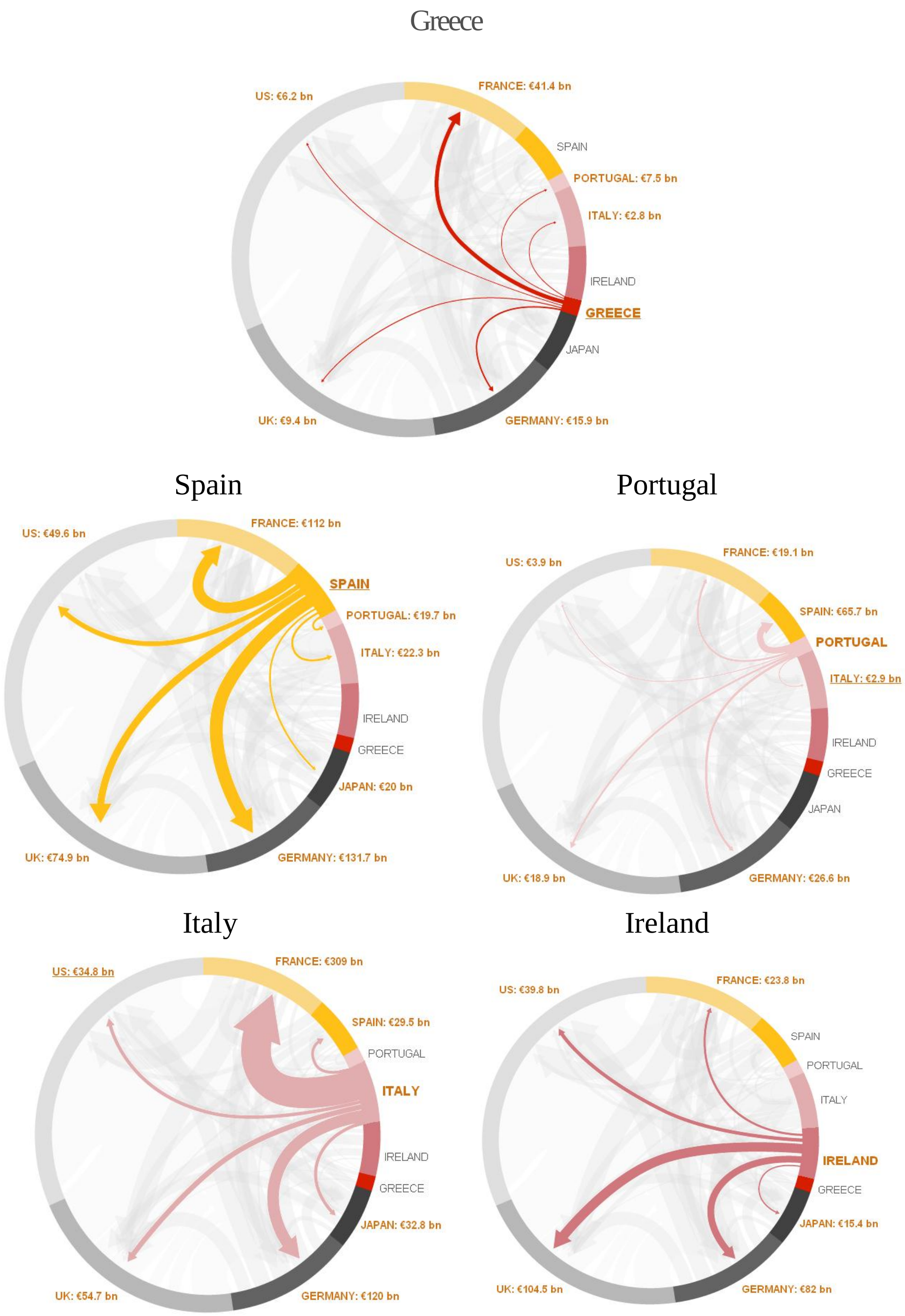

Figure 5. Euro stability indicators

Euro stability indicators based on the 3-months risk-neutral distribution of options on the dollar-euro exchange rate. VaR ratio refers to the indicator based on the Value-at-Risks measure and ES ratio refers to the indicator based on the expected shortfall measure.

Table 1 : Summary Statistics: CDS spreads per country

	BE	FR	DE	NL	FL	A	IR	ES	PT	GR	IT
Overall sample period *from 05/09/2008 to 31/01/2012*											
Mean	127	79	47	56	40	99	366	198	384	970	191
Median	115	69	41	46	33	85	255	188	266	688	162
Maximum	406	250	119	140	91	269	1192	491	1527	5047	592
Minimum	21	12	8	11	11	11	11	39	39	52	41
Std.Dev	84	54	24	29	19	48	270	115	366	1086	128
Skewness	0.99	1.35	1.10	1.04	1.03	1.27	0.46	0.55	1.03	1.54	1.54
Kurtosis	0.15	1.18	0.49	0.02	-0.07	1.40	-1.03	-0.83	-0.19	1.27	1.46
Q1	56	40	32	35	28	69	150	94	82	172	106
Q3	161	91	56	68	50	119	615	266	548	1040	199
Subprime crisis *from 05/09/2008 to 13/10/2009*											
Mean	67	42	38	59	41	107	140	89	81	160	113
Median	61	39	35	48	37	100	151	87	75	147	104
Maximum	157	98	91	129	90	269	386	169	161	298	199
Minimum	21	12	8	11	11	11	11	39	39	52	41
Std.Dev	33	20	19	31	20	56	111	29	29	62	45
Skewness	0.97	0.85	1.09	0.58	0.63	0.80	0.23	0.69	0.70	0.38	0.36
Kurtosis	0.21	0.34	1.12	-0.75	-0.32	0.92	-0.95	0.09	-0.34	-0.77	-1.11
Q1	39	26	24	34	25	72	11	68	57	118	75
Q3	80	55	46	86	58	138	219	100	97	212	158
Sovereign debt crisis *from 14/10/2009* to *31/01/2012*											
Mean	156	96	52	55	39	95	474	250	529	1359	229
Median	139	79	44	46	31	82	555	242	445	925	180
Maximum	406	250	119	140	91	241	1192	491	1527	5047	592
Minimum	33	20	19	24	17	48	111	66	51	123	68
Std.Dev	86	56	24	28	18	43	256	105	364	1131	137
Skewness	0.61	1.03	1.03	1.33	1.25	1.58	0.01	0.12	0.57	1.12	1.16
Kurtosis	-0.51	0.13	-0.02	0.63	0.14	1.50	-1.24	-0.80	-0.90	-0.02	0.07
Q1	93	64	37	35	28	68	199	180	245	677	138
Q3	213	108	59	60	39	98	688	342	837	1751	248

Note: Entries correspond to Q1 (first quantile), Q3 (third quantile), BE (Belgium), FR (France), DE (Germany), NL (Netherlands), FL (Finland), A (Austria), IR (Ireland), ES (Spain), PT (Portugal), GR (Greece), IT(Italy). Statistics are computed based on daily data and are expressed in basis points except for Skewness and Kurtosis. The total number of observations is 882 for the whole sample period , 288 for the first sub-period and 594 for the second.

Table 2 : Summary Statistics: Implied Volatilities for puts

PUT	10 Delta				25 Delta				At the Money			
	1M	**3M**	**6M**	**9M**	**1M**	**3M**	**6M**	**9M**	**1M**	**3M**	**6M**	**9M**
Overall sample period *from 05/09/2008 to 31/01/2012*												
Mean	15.42	16.44	17.00	17.24	14.23	14.78	15.04	15.16	13.40	13.67	13.82	13.88
Median	14.34	15.35	16.19	16.53	13.45	14.01	14.47	14.62	12.55	12.93	13.25	13.35
Maximum	33.60	28.65	25.55	24.33	31.05	25.70	22.49	20.95	29.00	24.25	21.70	20.15
Minimum	9.75	6.10	6.40	12.59	9.10	5.28	5.35	11.41	8.95	5.00	5.00	10.63
Std.Dev	4.15	3.46	2.93	2.66	3.64	2.94	2.39	2.12	3.48	2.79	2.23	1.94
Skewness	1.27	1.02	0.67	0.60	1.36	1.12	0.74	0.73	1.48	1.37	1.07	1.11
Kurtosis	1.36	0.48	-0.19	-0.67	1.91	1.03	0.41	-0.31	2.18	1.74	1.30	0.67
Q1	12.20	13.80	14.80	15.26	11.45	12.58	13.25	13.55	10.80	11.70	12.25	12.49
Q3	17.56	18.43	18.93	19.25	15.93	16.28	16.53	16.56	14.80	14.80	14.70	14.72
Subprime crisis *from 05/09/2008 to 13/10/2009*												
Mean	17.49	17.74	17.65	17.70	16.34	16.18	15.88	15.80	15.95	15.66	15.22	15.11
Median	15.76	16.06	16.34	16.54	14.88	15.05	15.03	15.00	14.85	14.80	14.68	14.53
Maximum	33.60	28.65	25.55	24.33	31.05	25.70	22.49	20.95	29.00	24.25	21.70	20.15
Minimum	9.75	6.10	6.40	12.59	9.10	5.28	5.35	11.41	9.00	5.00	5.00	10.63
Std.Dev	5.51	4.64	3.92	3.45	4.81	3.94	3.23	2.80	4.46	3.60	2.96	2.51
Skewness	0.56	0.44	0.22	0.21	0.57	0.42	0.13	0.22	0.51	0.37	0.05	0.19
Kurtosis	-0.72	-1.05	-1.15	-1.47	-0.54	-0.87	-0.79	-1.37	-0.61	-0.77	-0.54	-1.22
Q1	12.59	13.56	13.98	14.45	12.22	12.68	13.06	13.33	12.03	12.60	12.79	13.10
Q3	22.11	22.13	21.50	21.20	20.14	19.68	18.71	18.45	19.40	18.71	17.75	17.41
Sovereign debt crisis *from 14/10/2009* to *31/01/2012*												
Mean	14.42	15.81	16.69	17.01	13.21	14.10	14.64	14.85	12.17	12.71	13.13	13.28
Median	13.83	15.23	16.16	16.50	12.95	13.73	14.27	14.48	11.85	12.38	12.90	13.06
Maximum	22.45	23.13	22.94	22.83	19.88	20.05	19.60	19.47	18.10	17.55	17.05	16.88
Minimum	10.23	11.49	12.19	12.62	9.50	10.83	11.75	12.15	8.95	9.95	10.70	11.07
Std.Dev	2.80	2.49	2.24	2.15	2.29	1.97	1.72	1.62	1.91	1.56	1.30	1.20
Skewness	0.85	0.77	0.78	0.78	0.71	0.65	0.72	0.75	0.65	0.61	0.62	0.69
Kurtosis	-0.13	-0.28	-0.24	-0.21	-0.22	-0.29	-0.19	-0.09	-0.28	-0.33	-0.16	0.00
Q1	12.89	14.48	15.64	16.03	11.30	12.52	13.30	13.61	10.60	11.50	12.10	12.34
Q3	15.78	17.19	17.87	18.11	14.45	15.24	15.58	15.72	13.34	13.79	13.95	13.99

Note: OTC European quotes at fixed maturities 1, 3 , 6 , 9 months of out-of-the-money put (10-20-delta) and at-the-money-options (50-delta). The quotes are in terms of delta-implied-volatilities of Black-Scholes. Statistics are computed based on daily data. The overall sample period spans from 05/09/2008 to 31/01/2012. The first sub-period (subprime crisis) is from 05/09/2008 to 13/10/2009 and the second sub-period (sovereign debt crisis) is from 14/10/2009 to 31/01/2012.

Table 3 : Summary Statistics: Implied Volatilities for calls

Call	10 Delta				25 Delta			
	1M	3M	6M	9M	1M	3M	6M	9M
Overall sample period *from 05/09/2008 to 31/01/2012*								
Mean	13.22	13.76	14.16	14.39	13.01	13.28	13.46	13.57
Median	11.95	12.80	13.38	13.62	12.03	12.50	12.89	13.06
Maximum	28.68	27.55	24.83	23.95	28.05	25.08	22.35	21.00
Minimum	8.38	6.30	6.70	10.74	8.43	5.13	5.45	10.64
Std.Dev	3.96	3.44	2.99	2.76	3.58	2.95	2.43	2.14
Skewness	1.61	1.61	1.44	1.42	1.57	1.54	1.37	1.41
Kurtosis	2.18	2.09	1.44	1.31	2.33	2.17	1.69	1.47
Q1	10.60	11.63	12.16	12.46	10.50	11.40	11.85	12.14
Q3	14.20	14.30	14.78	15.25	14.06	13.95	14.03	14.07
Subprime crisis *from 05/09/2008 to 13/10/2009*								
Mean	16.98	17.24	17.26	17.38	16.06	15.89	15.64	15.57
Median	16.24	16.50	16.64	16.89	15.19	15.21	15.15	15.01
Maximum	28.68	27.55	24.83	23.95	28.05	25.08	22.35	21.00
Minimum	9.65	6.30	6.70	11.43	9.10	5.13	5.45	10.64
Std.Dev	4.69	3.92	3.30	2.88	4.43	3.62	2.97	2.50
Skewness	0.41	0.38	0.08	0.21	0.47	0.36	0.04	0.22
Kurtosis	-0.80	-0.73	-0.62	-0.82	-0.69	-0.71	-0.46	-1.00
Q1	12.75	14.07	14.68	15.25	12.10	12.98	13.23	13.74
Q3	20.34	20.39	20.05	19.83	19.38	18.76	18.13	17.72
Sovereign debt crisis *from 14/10/2009* to *31/01/2012*								
Mean	11.40	12.08	12.65	12.95	11.52	12.02	12.41	12.60
Median	11.20	12.08	12.65	12.91	11.43	11.90	12.35	12.52
Maximum	16.75	15.63	15.41	15.24	16.88	15.95	15.55	15.36
Minimum	8.38	9.63	10.41	10.74	8.43	9.43	10.25	10.68
Std.Dev	1.57	1.20	1.02	0.94	1.67	1.30	1.04	0.93
Skewness	0.47	0.10	0.05	0.11	0.44	0.27	0.27	0.29
Kurtosis	-0.27	-0.55	-0.86	-0.86	-0.38	-0.50	-0.47	-0.40
Q1	10.62	11.15	11.81	12.08	10.18	11.03	11.58	11.86
Q3	12.46	12.98	13.50	13.71	12.52	13.00	13.22	13.30

Note: OTC European quotes at fixed maturities 1, 3, 6 and, 9 months of out-of-the-money call (10-20-delta) options. The quotes are in terms of delta-implied-volatilities of Black-Scholes.

Table 4: Summary statistics of risk-neutral moments and the dollar-euro exchange rate

	Exchange rate	risk-neutral Skewness	risk-neutral Kurtosis	risk-neutral Volatility
		Overall sample period *from 05/09/2008 to 31/01/2012*		
Mean	1.37	-0.10	5.85	0.15
Median	1.37	-0.24	5.12	0.14
Maximum	1.51	1.58	15.12	0.27
Minimum	1.19	-0.91	3.90	0.06
Std.Dev	0.07	0.46	1.61	0.03
Skewness	-0.13	0.60	2.16	1.41
Kurtosis	-0.75	-0.34	5.22	1.75
Q1	1.31	-0.41	4.88	0.12
Q3	1.42	0.29	6.25	0.16
		Subprime crisis *from 05/09/2008 to 13/10/2009*		
Mean	1.36	0.47	7.64	0.17
Median	1.36	0.45	7.06	0.16
Maximum	1.49	1.58	15.12	0.27
Minimum	1.25	-0.17	5.04	0.06
Std.Dev	0.07	0.25	1.75	0.04
Skewness	-0.07	1.06	1.34	0.41
Kurtosis	-1.22	2.57	2.05	-0.90
Q1	1.30	0.30	6.28	0.13
Q3	1.42	0.56	8.61	0.20
		Sovereign debt crisis *from 14/10/2009* to *31/01/2012*		
Mean	1.37	-0.37	4.99	0.14
Median	1.37	-0.36	4.96	0.13
Maximum	1.51	0.29	5.94	0.19
Minimum	1.19	-0.91	3.90	0.10
Std.Dev	0.07	0.23	0.25	0.02
Skewness	-0.16	-0.01	0.75	0.66
Kurtosis	-0.59	-0.22	1.62	-0.18
Q1	1.32	-0.54	4.78	0.12
Q3	1.42	-0.23	5.12	0.15

Note: Statistics are computed based on daily data. The overall sample period spans from 05/09/2008 to 31/01/2012. The first sub-period (subprime crisis) is from 05/09/2008 to 13/10/2009 and the second sub-period (sovereign debt crisis) is from 14/10/2009 to 31/01/2012.Skew, Kurt and IV, respectively: Skewness, kurtosis and implied volatility are the independent variables.

Table 5 : Regression Results: Risk-Neutral Moments

	Skewness		**Kurtosis**		**Volatility**	
	Betas	T-stat	Betas	T-stat	Betas	T-stat
Overall sample period *from 05/09/2008 to 31/12/2012*						
Belgium	0.008	0.09	0.529	1.48	0.022***	2.37
France	-0.010	-0.11	0.634	1.69	0.029***	2.94
Germany	0.047	0.05	0.858**	2.20	0.024***	2.34
Netherlands	-0.020	-0.19	0.567	1.40	0.027***	2.64
Finland	-0.044	-0.39	0.423	0.94	0.024**	2.09
Austria	-0.001	-0.01	0.311	1.02	0.017**	2.14
Ireland	-0.082*	-1.84	-0.331*	-1.87	-0.003	-0.69
Spain	-0.074	-0.77	0.339	0.89	0.028***	2.82
Portugal	-0.049	-0.51	0.596	1.56	0.026***	2.66
Greece	-0.137	-1.45	0.135	0.36	0.013	1.37
Italy	-0.075	-0.75	0.608	1.53	0.033***	3.13
Subprime crisis *from 05/09/2008 to 13/10/2009*						
Belgium	0.089	0.54	0.569	0.76	0.016	0.93
France	0.082	0.43	0.774	0.89	0.034*	1.73
Germany	0.138	0.75	0.917	1.10	0.023	1.20
Netherlands	-0.005	-0.03	0.439	0.51	0.030	1.50
Finland	0.007	0.03	0.398	0.38	0.025	1.09
Austria	0.017	0.13	0.260	0.43	0.020	1.47
Ireland	-0.058	-0.86	-0.382	-1.26	-0.004	-0.63
Spain	-0.005	-0.02	0.272	0.26	0.028	1.16
Portugal	0.130	0.59	0.968	0.98	0.036	1.61
Greece	-0.100	-0.48	-0.120	-0.13	0.024	1.10
Italy	0.010	0.04	0.595	0.56	0.035	1.41
Sovereign debt crisis *from 14/10/2009* to *31/01/2012*						
Belgium	-0.128	-1.26	0.538**	2.16	0.031***	2.81
France	-0.090	-0.99	0.420*	1.86	0.019*	1.94
Germany	-0.097	-0.92	0.698***	2.66	0.021*	1.80
Netherlands	-0.092	-0.85	0.657***	2.45	0.022*	1.84
Finland	-0.150	-1.37	0.481*	1.78	0.022*	1.89
Austria	-0.004	-0.04	0.421*	1.76	0.010	0.97
Ireland	-0.223**	-2.14	0.627***	2.43	0.016	1.40
Spain	-0.145*	-1.77	0.383*	1.89	0.024***	2.71
Portugal	-0.203**	-2.25	0.467**	2.10	0.018*	1.78
Greece	-0.134	-1.54	0.383*	1.80	0.008	0.87
Italy	-0.174**	-2.00	0.540***	2.51	0.030***	3.05

Note: For each country, the dependent variables are the daily moments of the 3-months risk-neutral distribution of dollar-euro exchange rate options (the second moment is expressed in terms of annualized volatility). T-stats are computed based on the Wald test. . (***) indicates statistical significance at the 1 percent level, (**) at the 5 percent level and (*) at the 10 percent level.

Table 6 : Regression Results: Value-at-Risk and Expected Shortfall ratios

	VaR ratio		**ES ratio**	
	Betas	T-stat	Betas	T-stat
Overall sample period *from 05/09/2008 to 31/12/2012*				
Belgium	-0.01	-0.315	-0.03	-0.585
France	-0.05	-1.114	-0.06	-1.000
Germany	-0.01	-0.282	-0.02	-0.392
Netherlands	-0.04	-0.771	-0.06	-0.853
Finland	-0.07	-1.202	-0.09	-1.264
Austria	-0.02	-0.621	-0.04	-0.876
Ireland	-0.04	-1.925	-0.04	-1.411
Spain	-0.07	-1.404	-0.08	-1.290
Portugal	-0.05	-1.100	-0.06	-1.010
Greece	-0.06	-1.123	-0.06	-1.292
Italy	-0.09*	-1.750	-0.10	-1.503
Subprime crisis *from 05/09/2008 to 13/10/2009*				
Belgium	0.03	0.365	0.00	-0.014
France	-0.02	-0.192	-0.02	-0.159
Germany	0.02	0.199	0.02	0.156
Netherlands	-0.03	-0.374	-0.05	-0.442
Finland	-0.05	-0.478	-0.08	-0.517
Austria	-0.02	-0.251	-0.04	-0.500
Ireland	-0.03	-0.864	-0.02	-0.462
Spain	-0.05	-0.416	-0.04	-0.272
Portugal	0.02	0.220	0.03	0.191
Greece	-0.01	-1.151	-0.03	-0.951
Italy	-0.08	-0.740	-0.07	-0.445
Sovereign debt crisis *from 14/10/2009* to *31/01/2012*				
Belgium	-0.08	-1.518	-0.09	-1.359
France	-0.08	-1.573	-0.09	-1.423
Germany	-0.07	-1.298	-0.10	-1.404
Netherlands	-0.06	-1.078	-0.08	-1.119
Finland	-0.09	-1.554	-0.12	-1.674
Austria	-0.01	-0.274	-0.02	-0.269
Ireland	-0.12**	-2.195	-0.14**	-2.007
Spain	-0.08*	-1.925	-0.11**	-1.991
Portugal	-0.10**	-2.024	-0.12**	-2.006
Greece	-0.07	-1.571	-0.10	-1.464
Italy	-0.12***	-2.495	-0.15***	-2.530

Note: For each country, the dependent variables are the Value-at-Risk ratios and Expected Shortfall ratios of the daily moments of the 3-months risk-neutral distribution of dollar-euro exchange rate options (the variance is expressed in terms of annualized volatility). T-stats are computed based on the Wald test. . (***) indicates statistical significance at the 1 percent level, (**) at the 5 percent level and (*) at the 10 percent level.