1. Introduction

Well-known examples of financial crises include1980s and 1990s S&L crisis, 2007 subprime mortgage crisis, and 2010 European sovereign debt crisis, in the period of financial crises, losses tend to spread across financial institutions. Financial institutions are usually closely interlinked, so rocking one will shake the whole structure. Beside, as we know, the risks can spread among financial institutions, industries, and countries. Therefore, these events can also send shock waves through global financial markets and threaten the supply of credit to the real economy. Contagious failures might result from small shocks and cause systemic risk.

Systemic risk－the risk that the institutional distress spreads and collapses the entire financial system with potentially adverse consequences for the supply of credit to the real economy. Babus and Carletti [1] analyze the risk of contagion where the failure of one financial institution leads to the default of other financial institutions though a domino effect. Herring and Wachter [2] and Reinhart and Rogoff [3] have found that a collapse of residential or commercial real estate value is the main cause for system wide failures of financial institutions during many financial crises. Brunnermeier, Crocket, Goodhart, Perssaud, and Shin [4] classify the financial institutions into" individually systemic" and "systemic as part of a herd " institutions.

Individually systemic institutions are so interconnected and large that they can cause negative risk spillover effects on others. This kind of institutions has two characters: "too big to fail" and "too interconnected to fail". Systemic as part of a herd institutions can also spread the negative effect to others. These institutions' size is usually small. However, a large number of these institutions that act like clones can be as precarious and dangerous to the system as the large merged identity. 1980s and 1990s S&L crisis is one of the examples that many small institutions being systemic as part of herd. S&Ls made long-term loans at fixed interest using short-term money. When the interest rate increased, the S&Ls could not attract adequate capital and became insolvent rather than admit to insolvency, some CEOs of S&Ls became reactive by inventing creative accounting strategies that let their businesses looked highly profitable, thereby attracting more investors and growing rapidly, while actually losing money.

We concern about how contagion arises. As financial institutions have very large amounts of trades across various counterparties, credit risk spreads to other financial sectors, causing several liquidity problems (Diamond and Rajan [5]). Allen and Gale [2] indicate that banks are linked ex-ante, in the former through a banker's bank where investments are pooled, and in the latter through interbank loans. When the realized liquidity demand exceeds the supply, linked banks have to fail. However, contagion can occur even if there are no explicit links between banks ex-ante because of the negative real spillover effect of bank failure on the available liquidity. Banks are linked by a common market for liquidity. The risk caused by a shock also contagion rapidly from one country to another even though the two countries are not explicated connected by Longstaff [7]. Clearly, credit risk is one of the propagation mechanisms for liquidity problem.

There are many literatures on contagion effects, but the earlier studies on credit risk contagion and spillovers to other countries are rare. In this paper, we focus our attention on the liquidity problem spreads across countries.

The traditional measure of risk is VaR, which was developed for the standard tool for measuring market risk. Development was most extensive at J. P. Morgan, which published the methodology and gave free access to estimates of the necessary underlying parameters in 1994. This was the first time VaR had been exposed beyond a relatively small group of quants.

VaR calculates the worst expected loss over a given horizon at a given confidence level under normal market conditions. The q%-VaR is maximum dollar loss with the (1-q) % confidence level. Different choices of horizon and confidence level will result in trivially different VaR number. If the distribution can be assumed to be normal, VaR can be derived directly from the portfolio standard deviation by using a multiplicative factor that is a function of the confidence level. But many empirical evidences show that the returns are fat tail and leptokurtic distribution. A fat-tailed distribution is a probability distribution with the heavy-tailed distributions, that they exhibit extremely large skewness or kurtosis.

In 1978 Koenker and Bassett [8] introduced a new class of statistics for the linear model, which have been called "regression quantiles" since they appear to have analogous properties to the ordinary sample quantiles of the location model. But they didn’t be extensively used until now.

The extreme sensitivity of the least squares estimator to modest amounts of outlier contamination makes it a very poor estimator in many non-Gaussian, especially long-tailed, situations. Since the empirical risk observations usually are tail observations. For instance, if the data are short, after a string of good news, risk seems docile. It causes adverse movement and lead to sizable increase. But when extreme crisis happens, the estimated risk measure may sharply increase. Least squares estimation provides a method of estimating such conditional mean models. Quantile regression provides a method for estimating models for conditional quantile functions.

There was a parallel early recognition of the need for robust alternatives to the least squares estimator for the linear model. Wild observations or "outliers" as they came to be called were more difficult to identify in such models and the fruitful notion from the location model of an ordering of sample observations had no simple analogue in the more complicated models.

VaR_q^i is implicitly defines as the q quantile.

$\Pr(X^i \leq VaR_q^i)$=q

Where X^i is the variable of sector i for which the VaR_q^i is defined.

The Basel Committee on Bank Supervision announced in 1995 that capital adequacy requirement for banks are to be based on VaR. Basel II contains three pillars concept-(i) minimum capital requirements (ii) supervisory review (iii) market discipline. Pillar 1 is a regulatory standard for minimum capital requirements. And the first pillar handles maintenance of regulatory capital calculated for three major components of risk that a bank faces: credit risk, operational risk, and market risk.

Nevertheless, the single sector's risk measure does not really reflect systemic risk. Jorion [9] and Kupiec [10] indicated that the value at risk(VaR)－focuses on the risk of an individual institution in isolation. When the financial crises happen, loss tends to spread across the financial sectors. Therefore, set financial regulation that is solely based on individual risk of an sector in isolation does not necessarily insulate the financial sector against systemic risk. Any regulation bases on contemporaneous risk measure estimates would amplify the negative effect and cannot be used to anticipate systemic risk. It would be unnecessarily rigid after adverse events and unnecessarily loose

Adrian and Brunnermeier [11] use quantile regression to capture the empirical relationship between VaRs in the tail of the joint distribution, CoVaR. In order to emphasize the systemic nature of this risk measure, adding to VaR the prefix “Co”, which stands for conditional, contagion, comovement, or contributing. They focus primarily on CoVaR, where institution i’s CoVaR relative to the system is defined as the VaR of the whole financial sector conditional on institution i being in distress (the CoVaR of an institution is proportional to the covariance of the system and the individual institution).

CoVaR focuses on the tail distribution, and estimates of CoVaR for different q can get an assessment of the degree of systemic risk contribution for different degreed of tailness. And the different between the CoVaR conditional on the normal state of the financial market and the CoVaR conditional on the distress of the particular financial market, ΔCoVaR, quantifies how much a sector adds to overall systemic risk. It does not like the traditional risk measures focus on the risk of individual financial market. CoVaR measures externalities, together with fundamental comovement, and it also relates to econometric work on contagion and spillover effects.

A number of systemic risk measures have been proposed. Billio, Getmansky, Lo, and Pelizzon [12] provide an overview of several systemic risk measures in the economics and finance literature. Lehar, Gauthier, and Souissi [13]have access to a unique data set of the Canadian banking system, which includes individual banks' risk exposures as well as detailed information on interbank linkages including OTC derivatives. The Co-Risk measure of International Monetary Fund (2009) examines the CDS spread of one institution, conditional on the CDS spread of the other, each at the respective 95th percentile of its empirical distribution. The structure is similar to CoVaR.

The objective of our paper is twofold: First, we base on CoVaR model to measure the spreading of systemic risk across countries. Also, even though some countries have no direct linkage, one country falls into distress, whether credit risk of individual country increases or not.

The Black Swan's author, Taleb (2006) [14], warns that:

Globalization creates interlocking fragility, while reducing volatility and giving the appearance of stability. In other words it creates devastating Black Swans. We have never lived before under the threat of a global collapse. Financial Institutions have been merging into a smaller number of very large banks. Almost all banks are interrelated. So the financial ecology is swelling into gigantic, incestuous, bureaucratic banks – when one fails, they all fall. The increased concentration among banks seems to have the effect of making *financial crises less likely, but when they happen they are more global in scale and hit us very hard. We have moved from a diversified ecology of small banks, with varied lending policies, to a more homogeneous framework of firms that all resemble one another. True, we now have fewer failures, but when they occur ….I shiver at the thought.*

Credit risk reflects that the risk of a borrower will fail to make payments which it is obligated to do and default on the debt. And the lender will lost principal and interest, disruption to cash flows, and increased collection costs. In general, the risk increases and the higher will be the interest rate. Moreover, it can be the risk of loss arising from a sovereign state freezing foreign currency payments or when it defaults on its obligations. And the liquidity is a major channel by which contagion effects can be propagated through different economic sectors. When one financial market falls into distress, it can result in a decrease of overall liquidity of all financial markets. Furthermore, this may affect investor behavior and asset price. A key implication of this liquidity-related channel of contagion is that a distress event may be associated with subsequent declines in the availability of credit. Note that this spiraling mechanism might play out over an extended period by Longstaff [15].

Melvin and Taylor [16] indicate that the period of 2007-2009 U.S. subprime problem would become a global issue and led to severe liquidity problems in several foreign markets, as the enormous change in interbank interest rate. Kodres and Pritsker [17] present a model in which contagion occurs as losses in one market force economic agents to either liquidate leveraged positions or to rebalance their portfolios in response. Brunnermeier and Pedersen [18] argue that agents who experience losses in one market may find their ability to obtain funding impaired, which would then result in declines in the liquidity of the other financial assets in the markets. A key implication of this liquidity-related channel of contagion is that a distress event may be associated with subsequent declines in the availability of credit and increases in trading activity in other markets. Note that this spiraling mechanism might play out over an extended period.

According to the CoVaR model that Adrian and Brunnermeier [11] address, we want to capture the credit risk contagion propagated from one country to another, and in the remainder of the paper, we use conditional VaR and ΔCoVaR estimates that the time variation of the joint distribution of interest rate spread as a function of lagged systemic state variable. The state variables include the volatility index of stocks, exchange rate, and the prices of oil and gold.

During the period of 2007-2009 financial crisis, U.S. subprime mortgage event cause several liquidity problems in many foreign countries. In our paper, we use CoVaR captures the increase in credit risk of one European country when United

States falls into distress. Of course, it also can capture that one European country's distress cause risk spillovers onto United States. In the paper, we totally choose eight European countries to focus on the credit risk spills across countries, and these eight European countries include UK, Germany, France, Portugal, Ireland, Italy, Greece, and Spain. One of the reasons why we use these European countries' data is we focus primarily on the credit risk spills across countries. The economies of Portugal, Ireland, Italy, Greece, and Spain are high national budget deficits relative to GDP, and high government debt levels. European sovereign debt crisis is difficult for these countries to repay their government debt without the assistance of third parties.

Since we want to capture the credit risk of US, our estimate of credit risk is based on the changes in the TED spread (ΔTED). An interest rate spread measures the difference in interest rates between two bonds of different risk. These credit spreads had shrunk to historically low levels during the ―liquidity bubble but they began to surge upward in the summer of 2007. Historically, many market observers focused on the TED spread, the difference between the risky LIBOR rate and the risk-free U.S. Treasury bill rate. In times of uncertainty, banks charge higher interest for unsecured loans, which increases the LIBOR rate. Further, banks want to get first-rate collateral, which makes holding Treasury bonds more attractive and pushes down the Treasury bond rate. For both reasons, the TED spread widens in times of crises

(M.K. Brunnermeier [19]). Why are banks so reluctant to lend? One possibility is that they worry about borrower credit risk, though worries need to be extreme to justify the complete cessation of term lending. A second is that they may worry about having enough liquidity of their own, if their creditors demand funds. Yet, the many Federal Reserve facilities that have been opened should assuage these concerns(Diamond and Rajan [20]). Similarly, we use ΔIBOR to stand the European country's interest rate spread. European interbank offered rates (IBORs) serve as an indicator of levels of demand and supply in European financial market.

We calculate conditional measures of Δ CoVaR using daily data from January 1, 1999 to November 1, 2012. Consider the upside risk of changes in interest rate The conditional model variation of Δ CoVaR as a function of state variable at the 95% and 99% quantiles.

The advantages to CoVaR measure that are: (i) unlike traditional risk measures just focus on the individual sectors' risk, Δ CoVaR can address the contribution of U.S. credit risk to European countries' liquidity risk. (ii) this co-risk measure $\Delta\,\text{CoVaR}^{j|i}$ study the risk spillovers from sector to sector. For example, $\Delta\,\text{CoVaR}^{j|US}$capture the increase in risk of European country j when U.S. financial system falls into distress.

CoVaR is directional, which means that $\Delta\text{CoVaR}^{i|j}$ capture the increase in the risk of a country j when country i fall into distress. So it means that country i causes the risk spillover effect on country j. However, country j might not causes no risk on country i. Hence, $\Delta \text{CoVaR}^{i|j}$ is no reason should be equal to $\Delta \text{CoVaR}^{j|i}$, we will show that in our paper.

The paper is composed of five chapters. In Chapter 2, we describe the definition of VaR, CoVaR, and ΔCoVaR. We also present the estimation method via quantile regressions. Chapter 3 introduces the time-varying ΔCoVaR conditional on state variables and present estimates of these conditional ΔCoVaR. In Chapter 4, we compare the two conditional ΔCoVaR models. And we make the conclusion in Chapter 5.

2. VaR, CoVaR , Δ CoVaR

2.1 Quantile Regression

Let $\{Y_t$: t = 1, . . . ,T}be a random sample on a random variable Y having distribution function F. Then the θ_{th} sample quantile, 0 < θ < 1, may be defined as any solution to the minimization problem:

$$\min_q \sum_{Y \geq q} \theta|y-q| + \sum_{Y<q}(1-\theta)|y-q| \quad (1)$$

If Y are continuous random variables, which have cumulative distribution function F.

$$q_Y = F_Y^{-1}(\theta) = inf\{y: F_Y(y) \geq \theta\} \quad (2)$$

$$\min_q \left[\theta \int_{Y>q}|y-q|\, dF_Y(y) + (1-\theta)\int_{Y<q}|y-q| dF_Y(y)\right] \quad (3)$$

$$=\min_q \left[\theta \int_{Y>q}(y-q)\, dF_Y(y) - (1-\theta)\int_{Y<q}(y-q) dF_Y(y)\right] \quad (4)$$

F.O.C.

$$-\theta \int_{Y>q} dF_Y(y) + (1-\theta)\int_{Y<q} dF(y)=0 \quad (5)$$

$$\Rightarrow \; -\theta[1-F_Y(q)] + (1-\theta)F_Y(q)=0 \quad (6)$$

$$\Rightarrow \; F_Y(q) = \theta \quad (7)$$

Adrian and Brummer(2011) [11] use quantile regressions to describe estimation of the time-varying, conditional $CoVaR$.

$$X_t^i = \alpha^i + \gamma^i M_{t-1} + \varepsilon_t^i, \tag{8}$$

$$X_t^j = \alpha^{j|i} + \beta^{j|i} X_t^i + \gamma^{j|i} M_{t-1} + \varepsilon_t^{j|i} \tag{9}$$

The quantile regressions are definitely not the only way to estimate *CoVaR*. However, quantile regressions are an efficient way to deal with the data and estimate *CoVaR*. The quantile regressions incorporate estimates of the conditional mean and volatility to produce conditional quantiles, without the distributional assumptions that would be needed for estimation via OLS.

2.2 CoVaR Estimation

This section presents a methodology for estimating *CoVaR*. We adopt the *CoVaR* model by Adrian and Brunnermeier (2011) to know the spillover effects across the different countries.

Definition

For the downside risk, the *VaR* at the q-quantile is defined as:

$$\Pr(X^i \le VaR_q^i) = q \tag{10}$$

Where X^i is the variable of institution i. The VaR of institution j conditional on the specific event $C(X^i)$ of institution i, where q is the quantile. Mathematically:

$$\Pr(X^j \le CoVaR_q^{j|C(X^i)} \mid C(X^i)) = q \tag{11}$$

$$\Delta CoVaR_q^{j|i} = CoVaR_q^{j|X^i=VaR_q^i} - CoVaR_q^{j|X^i=Median^i} \quad (12)$$

$\Delta CoVaR_q^{j|i}$ denotes the different between the VaR of the country j's financial system conditional on the q% VaR of a particular country i 's financial system and the VaR of the country j's financial system conditional on the median state of the financial institution i. For instance, the VaR of j=Greece conditional on US financial system being at its VaR level - $\Delta\ CoVaR^{Greece|US}$, which reports Greece 's increase in value-at-risk in the case of US financial crisis. Furthermore, $\Delta CoVaR_q^{j|US}$ answers the question of which European country is most at risk should US financial crisis occur.

The different q allow an assessment of the degree of systemic risk contribution for different degrees of tailness. And this is the reason why we use quantile regressions in this paper as they are efficient use of data.

Now, we focus on the risk contagion from one country to another. We use CoVaR model to study the case where j= US, i.e., when the interest rate of U.S. financial system is at its VaR level. Recall that in order to measure the credit risk contagion spills from one country to another, we focus primarily on the 95% and the 99% quantiles.

$$\Pr(X^i \geq VaR_q^i)=q,$$

$$\Pr(X^j \geq CoVaR_q^{j|US} \mid US = VaR_q^{US})=q \quad (13)$$

Where $X^i = IR^i$ denotes the interest rate spread of country i, and VaR_q^i is implicitly defined by the q-quantile of the upside risk.

According to $CoVaR$ model by Adrian and Brunnermeier [11] and the idea of autoregressive process by Engle and Manganelli(2004) [21], we develop two time-varying $CoVaR$ models to estimate the conditional distribution as a function of state variables.

Model 1: Time-Varying CoVaR Model

We use the time-varying model introduced as above to measure eight European countries' $\Delta CoVaR$.

$$X_t^i = \alpha^i + \gamma^i M_{t-1} + \varepsilon_t^i, \tag{14}$$

$$X_t^j = \alpha^{j|i} + \beta^{j|i} X_t^i + \gamma^{j|i} M_{t-1} + \delta^{j|i} X_{t-1}^j + \varepsilon_t^{j|i} \tag{15}$$

Where M_t is a vector of state variables described in Table 3 and Table 4, and the one lag of the state variables are signifiedM_{t-1}. X_t^i denotes TED spread and X_t^j (ΔIBOR) denotes the difference between European IBOR and short term deposit interest rate . In order to capture the time variation in the joint distribution of X_t^i and X_t^j, the conditional distribution is estimated as a function of state variables. X_t^i is ΔIBOR and X_t^j is TED spread, provided that the contagion of interest rate risk spreads from European countries to US.

The definition of VaR and $CoVaR$:

$$VaR_{t,q}^{j} = inf\{\Pr(X_t^j \geq VaR_q | M_{t-1,} X_t^i) \geq q\} = F_{X_t^j}^{-1}(q | M_{t-1,} X_t^i) \quad (16)$$

$$CoVaR_{t,q}^{j|i} = inf\{\Pr(X_t^j \geq VaR_q | M_{t-1,} X_t^i = VaR_{t,q}^i, X_{t-1}^j) \geq q\}$$

$$=F_{X_t^j}^{-1}(q | M_{t-1,} VaR_{t,q}^i, X_{t-1}^j) \quad (17)$$

The conditional quantile function $F_{X_t^j}^{-1}(q | M_{t-1,} X_t^i)$ is the $VaR_{t,q}^j$ conditional on M_{t-1} and X_t^i. By conditioning on $X_t^i = VaR_{t,q}^i$, we also obtain the $CoVaR_{t,q}^{j|i}$ from the quantile function. In this case, $\Delta\, CoVaR$ means the difference.

We indicate time-varying $CoVaR_t$ and VaR_t with a subscript t and estimate the time variation conditional on a vector of lagged state variables.

A quantile regression consists of optimizing a modified function shown below for the quantile regression in (18) and (19):

VaR

$$\min_{\alpha_q, \gamma_q, \beta_q} \sum_t \begin{cases} q|X_t^i - \alpha_q - \gamma_q M_{t-1}|, & \text{if}(X_t^j - \alpha_q - \gamma_q M_{t-1}) \geq 0 \\ (1-q)|X_t^j - \alpha_q - \gamma_q M_{t-1}|, & \text{if}(X_t^j - \alpha_q - \gamma_q M_{t-1}) < 0 \end{cases} \quad (18)$$

CoVaR

$$\min_{\alpha_q,\gamma_q,\beta_q}\sum_t\begin{cases} q\left|X_t^j-\alpha_q-\gamma_q M_{t-1}-\beta_q X_t^i-\delta_q X_{t-1}^j\right|, & \text{if}(X_t^j-\alpha_q-\gamma_q M_{t-1}-\beta_q X_t^i-\delta_q X_{t-1}^j)\geq 0\\ (1-q)\left|X_t^j-\alpha_q-\gamma_q M_{t-1}-\beta_q X_t^i-\delta_q X_{t-1}^j\right|, & \text{if}(X_t^j-\alpha_q-\gamma_q M_{t-1}-\beta_q X_t^i-\delta_q X_{t-1}^j)<0 \end{cases} \quad (19)$$

Having estimated the quantile regression parameters, the predicted values of VaR and CoVaR are:

$$VaR_{t,q}^i=\hat{\alpha}_q^i+\hat{\gamma}_q^i M_{t-1}=X_{t,q}^i \quad (20)$$

$$Med=\hat{\alpha}_{50\%}^i+\hat{\gamma}_{50\%}^i M_{t-1}=X_{t,50\%}^i \quad (21)$$

$$CoVaR_{t,q}^{j|i}=\hat{\alpha}_q^{j|i}+\hat{\beta}_q^{j|i}VaR_{t,q}^i+\hat{\gamma}_q^{j|i}M_{t-1}+\hat{\delta}_q^{j|i}X_{t-1}^j=X_{t,q}^j \quad (22)$$

Then we can calculate $\Delta\,\mathrm{CoVaR}_t^{j|i}$ as:

$$\Delta\,\mathrm{CoVaR}_{t,q}^{j|i}=CoVaR_{t,q}^{j|i=VaR_{t,q}}-CoVaR_{t,q}^{j|i=Med_t}=\hat{\beta}_q^{j|i}(VaR_{t,q}^i-VaR_{t,50\%}^i) \quad (23)$$

Where $VaR_{t,50\%}^i$ means that country i is at its normal state (i.e. 50th percentile). In this paper, we focus on the systemic risk based on the tail covariation between countries. In this paper, we study primarily the 95% and the 99% quantiles.

Similarly, $\Delta\,CoVaR$ can also allow the study of risk spillover effects that institution i causes on institution j. Besides, when j=system, the superscript j is dropped. $\Delta\,\mathrm{CoVaR}_{t,q}^i$ estimates the contribution to which financial system stress increases conditional on the distress of a financial institution i.

Model 2: The lagged CoVaR Model

Being different from the model 1, we consider the lagged estimate time-varying $CoVaR_t$ and VaR_t with state variables.

In this model, we base on model one and use the lagged We use the time-varying model introduced as above to measure eight European countries' $\Delta\, CoVaR$.

$$X_t^i = \alpha^i + \gamma^i M_{t-1} + \varepsilon_t^i, \tag{24}$$

$$X_t^j = \alpha^{j|i} + \beta^{j|i} X_{t-1}^i + \gamma^{j|i} M_{t-1} + \delta^{j|i} X_{t-1}^j + \varepsilon_t^{j|i} \tag{25}$$

Where M_t is a vector of state variables described in Table 3 and Table 4, and the one lag of the state variables are signified M_{t-1}. X_t^i denotes TED spread and X_t^j denotes the difference between European IBOR and short term deposit interest rate . In order to capture the time variation in the joint distribution of X_t^i and X_t^j, the conditional distribution is estimated as a function of state variables.

The definition of VaR and $CoVaR$:

$$VaR_{t,q}^j = inf\{\Pr(X_t^j \geq VaR_q | M_{t-1,} X_{t-1}^i) \geq q\} = F_{X_t^j}^{-1}(q | M_{t-1,} X_{t-1}^i) \tag{26}$$

$$CoVaR_{t,q}^{j|i} = inf\{\Pr\left(X_t^j \geq VaR_q \middle| M_{t-1,} X_{t-1}^i = VaR_{t-1,q}^i, X_{t-1}^i\right) \geq q\}$$

$$= F_{X_t^j}^{-1}(q | M_{t-1,} VaR_{t-1,q}^i, X_{t-1}^i) \tag{27}$$

In this case, $\Delta\, CoVaR$ means the difference. We primarily study the case that

We indicate time-varying $CoVaR_t$ and VaR_t with a subscript t and estimate the time variation conditional on a vector of lagged state variables.

A quantile regression consists of optimizing a modified function shown below for the quantile regression in (28) and (29):

VaR

$$\min_{\alpha_q,\gamma_q,\beta_q} \sum_t \begin{cases} q\left|X_t^i - \alpha_q - \gamma_q M_{t-1}\right|, & \text{if}(X_t^j - \alpha_q - \gamma_q M_{t-1}) \geq 0 \\ (1-q)\left|X_t^j - \alpha_q - \gamma_q M_{t-1}\right|, & \text{if}(X_t^j - \alpha_q - \gamma_q M_{t-1}) < 0 \end{cases} \tag{28}$$

CoVaR

$$\min_{\alpha_q,\gamma_q,\beta_q} \sum_t \begin{cases} q\left|X_t^j - \alpha_q - \gamma_q M_{t-1} - \beta_q X_{t-1}^i - \delta_q X_{t-1}^j\right|, & \text{if}(X_t^j - \alpha_q - \gamma_q M_{t-1} - \beta_q X_{t-1}^i - \delta_q X_{t-1}^j) \geq 0 \\ (1-q)\left|X_t^j - \alpha_q - \gamma_q M_{t-1} - \beta_q X_{t-1}^i - \delta_q X_{t-1}^j\right|, & \text{if}(X_t^j - \alpha_q - \gamma_q M_{t-1} - \beta_q X_{t-1}^i - \delta_q X_{t-1}^j) < 0 \end{cases} \tag{29}$$

Having estimated the quantile regression parameters, the predicted values of VaR and CoVaR are:

$$CoVaR_{t,q}^{j|i} = \hat{\alpha}_q^{j|i} + \hat{\beta}_q^{j|i} VaR_{t-1,q}^i + \hat{\gamma}_q^{j|i} M_{t-1} + \hat{\delta}_q^{j|i} X_{t-1}^j = X_{t,q}^j \tag{30}$$

Then we can calculate $\Delta\,\mathrm{CoVaR}_t^{j|i}$ as:

$$\Delta\,\mathrm{CoVaR}_{t,q}^{j|i} = CoVaR_{t,q}^{j|i=VaR_{t,q}} - CoVaR_{t,q}^{j|i=Med_t} = \hat{\beta}_q^{j|i}(VaR_{t-1,q}^i - VaR_{t-1,50\%}^i) \tag{31}$$

Where $VaR_{t,50\%}^i$ means that country i's returns are at their median (i.e. 50th percentile). When j = U.S., $\Delta\,\mathrm{CoVaR}_{t,q}^{US|i}$ estimates country i's contribution to the credit risk of United States.

3. Data

3.1 Interest Rate Data

We get time variation of the risk measures by running quantile regressions of interest rates on the lagged state variables since credit spread is one of mechanisms for the liquidity problem. As what we mention in chapter1, in order to capture the credit risk of U.S. financial system, we adopt the TED spread. The TED spread is the difference between the interest rates on interbank loans and on short-term U.S. government debt (Treasury bill). When the TED spread increases, it is a sign that lenders believe the risk of default on interbank loans (counterparty risk) is increasing. Therefore, interbank lenders demand a higher rate of interest, or accept lower returns on safe investments such as T-bills. When the risk of bank defaults is considered to be decreasing, the TED spread decreases.

Initially, the TED spread was the difference between the three-month Eurodollars contract as represented by the London Interbank Offered Rate (LIBOR) and the interest rates for three-month U.S. Treasuries contracts. However, since the Chicago Mercantile Exchange dropped T-bill futures after the 1987 crash, the TED spread is now calculated as the difference between the three-month LIBOR and the three-month T-bill interest rate. The size of the spread is usually denominated in basis points (bps).

For example, if the T-bill rate is 5.10% and LIBOR at 5.50%, the TED spread is 40 bps. The TED spread is an indicator of perceived credit risk in the general economy. As treasury bills are considered risk-free while LIBOR reflects the credit risk of lending to commercial banks.

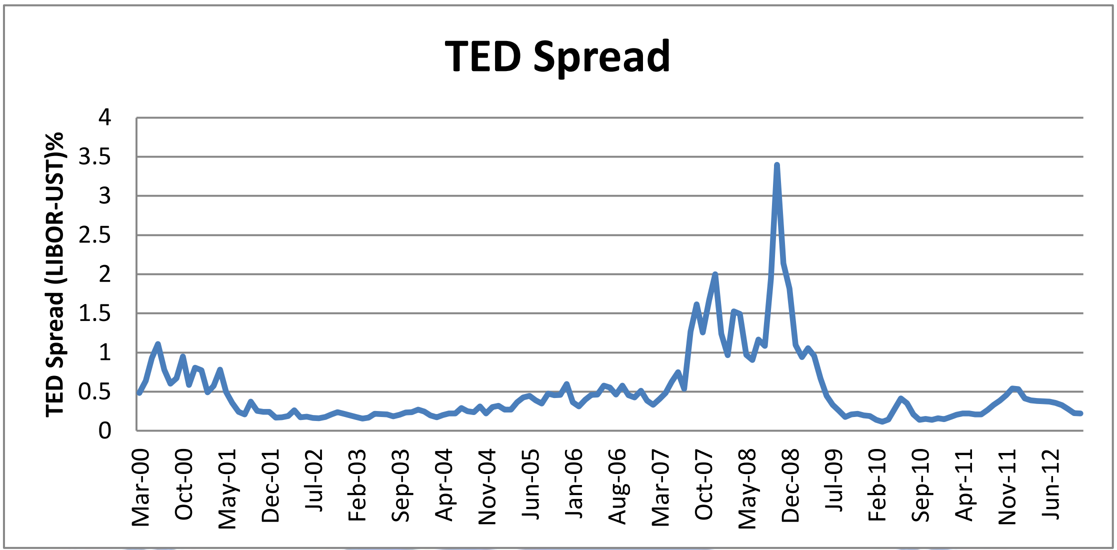

Figure1. Jan.2000~Nov.2012 TED spread

Sources: Datastream

As we can see from the line graph, TED spread fluctuates over these 12 years (Jan.2000~Nov.2012). In July 2007 the number stands at only 0.538 percent. Then, TED spread shoots up over the next two months, peaking at 1.616 percent in September. The number experiences a rise again, with December arriving at 1.999. During 2007, the subprime mortgage crisis balloons the TED spread to a region of 150–200 bps. Some higher readings for the spread are due to inability to obtain accurate LIBOR rates in the absence of a liquid unsecured lending market. But all of the numbers level off at fewer than two. Until October 2008, the number soars to

3.396 percent and reaches another new high after the Black Monday crash of 1987. More specifically, this is one month after Lehman Brother's bankruptcy filing which is the largest bankruptcy in U.S. history. During 2007-2009 the period of global financial crisis, the changes in interbank interest with large size reflect the risk of credit.

Our analysis focuses on VaR and $\Delta CoVaR$ of IBORs as they are most closely related to the supply of credit to the real economy. European interbank offered rates (IBORs) serve as an indicator of levels of demand and supply in European financial market. When the liquidity problems happen, leading banks would be charged more cost if borrowing from other banks. $\Delta IBOR^{j}$ denotes the difference between IBOR and one week deposit interest rate of European countries *j*.

Table1 provides the IBORs' statistic correlations between each European country we adopt. Table2 provides summary statistics for IBOR and TED Spread , we can see that the average IBOR of UK is the highest. But the maximum IBOR of European countries that Greece is greater by far than the others. The TED spread fluctuates over time but generally has remained within the range of 10 and 50 bps (0.1% and 0.5%) except in times of financial crisis. A rising TED spread often presages a downturn in the U.S. stock market, as it indicates that liquidity is being withdrawn.

Table 1: IBORs' statistic correlations

	UK	Germany	France	Porgaul	Ireland	Italy	Greece	Spain
UK	1	0.902861	0.889749	0.893013	0.896	0.892912	0.790734	0.898729
Germany	0.9029	1	0.994176	0.995844	0.998886	0.994699	0.931249	0.993397
France	0.8898	0.994176	1	0.996483	0.995806	0.991845	0.933692	0.992853
Portugal	0.8930	0.995844	0.996483	1	0.997161	0.994008	0.932253	0.993096
Ireland	0.8960	0.998886	0.995806	0.997161	1	0.995658	0.933606	0.994244
Italy	0.8929	0.994699	0.991845	0.994008	0.995658	1	0.929953	0.990827
Greece	0.7907	0.931249	0.933692	0.932253	0.933606	0.929953	1	0.928096
Spain	0.8987	0.993397	0.992853	0.993096	0.994244	0.990827	0.928096	1

Table 2: summary statistics

IBOR and TED Spread are expressed in basis points.

Country j	UK	Germany	France	Portugal	Ireland	Italy	Greece	Spain	Ted spread
Mean	3.7572	2.4075	2.4723	2.4241	2.4282	2.4219	3.4134	2.4345	0.5225
Median	4.6563	2.5100	2.5600	2.5279	2.5100	2.5113	2.5700	2.5200	0.3770
Maximum	8.0000	5.7500	5.1719	5.7775	5.7500	5.7886	13.3500	5.8500	4.5100
Minimum	0.4500	0.2400	0.0247	0.0247	0.0790	0.0405	0.8500	0.0700	0.0872
Std. Dev.	2.1718	1.4235	1.4288	1.4051	1.4102	1.4114	2.6156	1.4104	0.4764
Skewness	-0.5095	-0.0977	-0.1153	-0.0748	-0.0855	-0.1039	1.5028	-0.0882	2.9435
Kurtosis	1.8231	1.8879	1.8852	1.9361	1.8990	1.9346	4.3848	1.9338	15.7992

3.2 Time variation Associated with Systemic State Variables

Chapter 2 shows a methodology for estimating the time-varying CoVaR to measure U.S. credit risk contagion to European countries. We estimate the conditional distribution as a function of state variables, including local variables and global variables. The systemic state variables M_{t-1} are lagged. It is not appropriate to equate they with systemic risk factors, but rather as conditioning variables that are shifting the conditional mean and the conditional volatility of the risk measures.

Our sample starts from 1999 Jan. and ends in 2012 Nov (total about 14years). And we obtain daily data from Federal Reserve System, STOXX, and Datastream.

Table 3: State variables used in CoVaR estimation

State Variables(M_{t-1})
V2TX
EUFX
Stoxx
Gold
Oil

We can distribute the state variables into two types: local state variables and global state variables.

V2TX

The EURO STOXX 50 Volatility (VSTOXX) Short-Term Futures Index replicates the performance of a long position in constant maturity one-month forward one-month implied volatilities on the underlying EURO STOXX 50 Index. The index covers 50 stocks from 12 Eurozone countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. The EURO STOXX 50 Index is licensed to financial institutions to serve as underlying for a wide range of investment products such as Exchange Traded Funds (ETF), Futures and

Options, and structured products worldwide.

Further derived are the following single country indices: the EURO STOXX 50 Subindex France, the EURO STOXX 50 Subindex Italy and the EURO STOXX 50 Subindex Spain, covering components from France, Italy and Spain respectively. Liquidity spread measures the difference between the three-month repo rate and the three-month bill rate. We expect that higher liquidity spread tend to be associated with lower CoVaR.

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EUFX

Like many firms, financial institutions can be affected by exchange rate fluctuations. Exchange rates affect most directly those financial institutions with foreign currency transactions and foreign operations. They also can affect banks indirectly through their influence on the extent of foreign competition and the demand for loans, etc. And we obtain daily foreign exchange rates from Federal Reserve System. We expect this state variable has a positive relationship with CoVaR.

Stoxx

Dow Jones Euro Stoxx Volatility Index (Stoxx) is an index with a variable number of components. It represents large, mid and small capitalisation companies of 12 Eurozone countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.

In addition, we use the following two global variables that capture the time variation in global economy.

Oil Price and Gold Price

The global indexes include West Texas Intermediate crude oil price and Chicago Broad Exchange gold price index.

Comparing table and table, we can find that the values of 99%$\Delta CoVaR^{j|U.S.}$ are bigger than the values of 95%$\Delta CoVaR^{j|U.S.}$. This is matches our expectation that the more lower probability accompanies with higher risk spread.

If we want to measure the credit risks spread from European countries to US . We estimate the conditional distribution as a function of below state variables, including local variables and global variables.

Table 4: State variables used in CoVaR estimation

State Variables
VIX
USFX
SP500
Gold
Oil

VIX

This index is the ticker symbol for the Chicago Board Options Exchange (CBOE) Volatility Index, which is a popular measure of the implied volatility of S&P 500 index options. And it is often called the fear index as it represents one measure of the market expectation of stock market volatility. This volatility is meant to be forward looking and is calculated from both calls and puts. VIX is also a widely used measure of market risk. We expect that a higher VIX tends to be associated with larger risk due to the worst time for financial system includes the times when the VIX was highest.

USFX

As we discussed before exchange rates can affect financial stability indirectly through their influence on the extent of foreign competition and the demand for loans, etc. And we obtain daily foreign exchange rates from Federal Reserve System. We expect this state variable has a positive relationship with CoVaR.

SP500

Standard & Poor's 500 is a stock market index based on the common stock prices of 500 top publicly traded American companies, as determined by S&P.

In mid-2007 difficulties from subprime mortgage lending began spreading to the wider financial sector. The crisis became acute in September 2008, ushering in a period of unusual volatility, encompassing record 100-point moves in both directions and reaching the highest levels since 1929. It is one of the most commonly followed indices and many consider it the best representation of the market. Besides, it also has been classified common stocks as a leading indicator of business cycles and a bellwether for the U.S. economy. This index is interpreted as conditioning variables that are shifting the conditional mean and the conditional volatility of the credit risk measures. We expect the relationship between S&P 500 and $CoVaR$ is positive.

4. Estimation Results

The results of Model 1 are shown in Table7, Table8, Table9, and Table10. Each of the tables constitutes the estimated parameters and the estimates of our conditional q%- $CoVaR$ measures. We can clearly see the average $\Delta\ CoVaR_t^{j|US}$ of each year from 1999 to 2012. If we compare Table7 and Table8, we will find that $VaR_{99\%}^{US}$ (2.4013) is higher than $VaR_{95\%}^{US}$ (1.3581). And it makes senses that the upside risk of the change in interest rate is larger with 99% than 95%.

Table7 provides the estimate of our conditional 99%-$\Delta CoVaR_t^{j|US}$ measures that we obtain from quantile regressions. Recall that $\Delta\ CoVaR_t^{j|US}$ measures the marginal contribution of US financial system to European country j and indicates the difference between the value at risk of the European countries conditional on the stressed and the median state of US financial system. In 2008, 99%-$\Delta CoVaR_t^{j|US}$ of these eight European countries are higher than in the other years. To be more precise, Portuguese 99%-$\Delta CoVaR_t^{j|US}$is the highest while the value of UK is the lowest, and it is negative. We will discuss what is the mean of sign later.

We can see from the Table7 that the Portuguese coefficient of $VaR_{99\%}^{US}$ (0.1846) is higher than other European countries. More specifically, the parameter of UK ($\hat{\beta}^{\mathrm{UK}|US}$) is the smallest. The order of $\hat{\beta}^{\mathrm{j}|US}$is Portugal (0.1846), Italy (0.1254), and Spain (0.1131). Evidently, these three countries are related to sovereign debt markets. It might be consider that US financial situations play a pivotal role in these countries' finance and economy. The financial crisis and economic shock through credit market to transfer to other sectors.

The result of Table8 is similar to Table7, providing the estimate of our conditional 95%-$\Delta CoVaR_t^{j|US}$ measures that we obtain from quantile regressions. $\Delta\ CoVaR_t^{j|US}$ measures the marginal contribution of US financial system to European country j and indicates the difference between the value at risk of the European countries conditional on the stressed and the median state of US financial system.

Similarly, 95%-$\Delta CoVaR_t^{j|US}$ of these eight European countries in 2008 are higher than in the other years. To be more precise, Spanish 95%-$\Delta CoVaR_t^{j|US}$is the highest while the value of UK is the lowest, and it is negative.

We can see from the Table8 that the Spanish coefficient of $VaR_{95\%}^{US}$ (0.0785) is higher than other European countries. More specifically, the parameter of UK ($\hat{\beta}^{\mathrm{UK}|US}$) is the smallest. The order of $\hat{\beta}^{\mathrm{j}|US}$is Spain (0.0785), Greece (0.0672), and Ireland (0.0620). Where $\hat{\beta}^{\mathrm{j}|US}$s mean the degree of contribution to $CoVaR_t^{j|US}$by $VaR_t^{j|US}$, and they also denote the degree of contribution to $\Delta CoVaR_t^{j|US}$.

We obtain time variation of the risk measures by running quantile regressions of interest rate spreads on the lagged state variables. The regression coefficients of Table 7 and Table 8 report the directions of coefficients. The below table demonstrates that almost all IBOR spreads of eight European countries have positive contributions to $\Delta\ CoVaR_t^{j|US}$. The higher lagged spread between European IBOR and short term deposit interest rate tends to be associated with larger credit risk.

Table 5: The directions of Model1 regressions' coefficients

	99%-$\Delta CoVaR_t^{j\|US}$		95%-$\Delta CoVaR_t^{j\|US}$	
	> 0	< 0	> 0	< 0
VaR_t^{US}	7	1	7	1
$\Delta IBOR_{t-1}^{j}$	7	1	8	0

The direction of conditioning that we consider is $\Delta CoVaR_t^{j|US}$. Nonetheless, for credit risk questions, it is essential to compute the opposite conditioning, $\Delta CoVaR_q^{US|j}$, which is a measure of a European country's exposure to US wide distress.

$CoVaR$ is a VaR that conditions on a "bad event"- a conditioning that shifts the mean upwards, increases the variance, and increases higher moments. We mostly assume the bad event that country j is at its VaR level, occurs with probability q. We note that the average of $\Delta CoVaR_q^{US|j}$ including all European countries has a very close time series relationship with the value at credit risk of the US financial system, VaR_q^j, per construction.

As can be seen from the below table, all eight European countries' risk measure, VaR_q^j, are showed. The risk measure 99%-VaR of UK is the highest and 95%-VaR gives the similar result. As usual research, the paper will focus the study on values of VaR. However, in this paper these values are used to estimate $\Delta CoVaR$. If we want to study the marginal contribution to $\Delta CoVaR_q^{US|j}$, we should see the regression coefficients, $\hat{\beta}^{US|j}$, which determine the weight of VaR_q^j.

Table 6: The average VaR of each European country

Country j	UK	Germany	France	Portugal	Ireland	Italy	Greece	Spain
$VaR_{99\%}^j$	1.6005	0.4679	0.1287	0.3424	0.4707	0.6256	0.4607	0.4826
$VaR_{95\%}^j$	0.8865	0.1573	0.0393	0.0919	0.1410	0.1922	0.1504	0.1841

It can be clearly seen from Table9 that the parameter of Italy ($\hat{\beta}^{\text{US|Italy}}$) is negative and the smallest. The order of $\hat{\beta}^{\text{US}|j}$ is France (0.0662), Germany (0.0314), and UK (-0.0037). Where $\hat{\beta}^{\text{US}|j}$s mean the degree of contribution to $CoVaR_{t,99\%}^{US|j}$ by $VaR_{t,99\%}^{US|j}$, and they also denote the degree of contribution to $\Delta CoVaR_{t,99\%}^{US|j}$.

By contrast, the results of Tables 7 and 9 saw an opposite trend. In Table7, only $\hat{\beta}^{\text{UK}|US}$ is negative. However, in Table 9, $\hat{\beta}^{\text{US}|UK}$, $\hat{\beta}^{\text{US|Portugal}}$, $\hat{\beta}^{\text{US|Ireland}}$, $\hat{\beta}^{\text{US|Italy}}$, $\hat{\beta}^{\text{US|Greece}}$ and $\hat{\beta}^{\text{US|Spain}}$ are negative. So now, we are going to study what the means of negative $\hat{\beta}$s are.

In this paper, we focus on $CoVaR$ where country i's $CoVaR$ relate to the country j is defined as the VaR of country j conditional on country i being in distress. For example, the difference between the $CoVaR$ conditional on the distress of US financial system and the $CoVaR$ conditional on the normal state of the financial system, $\Delta CoVaR_q^{j|US}$, captures the marginal credit risk contribution of a particular country to the other country. The higher $\Delta CoVaR$ of country i indicates that it contributes more to country j. Now, we put our focus on discussing the negative $\Delta CoVaR$. According to the Table7, Table8, Table11, and Table12 only UK has negative $\Delta CoVaR$ while other European countries all have the positive values. The negative $\Delta CoVaRs$ result from the negative coefficients[1], $\beta^{UK|US}$, coefficients of $VaR^{UK|US}$. In contrast, Table9, Table10, Table13, and Table14 show that Portugal, Ireland, Italy, Greece, and Spain, which are Eurozone countries with the weakest economies, having the negative $\Delta CoVaR$.

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[1] We compute $\Delta CoVaR_{t,q}^{j|US} = CoVaR_{t,q}^{j|US} - CoVaR_{t,50\%}^{j|US} = \hat{\beta}^{j|US}\,(VaR_{t,q}^{j|US} - VaR_{t,50\%}^{j|US})$.
Where j=UK, $\hat{\beta}^{j|US}$=$\beta^{UK|US}$.

When a country in its VaR level, spillovers across countries can heighten counterparty credit risk. For example, positive $\Delta CoVaR_q^{j|i}$ captures the increase in credit risk of individual country j when country i falls into distress. However, there is a possible situation that when the investors hear about any financial crisis or there is shortage of liquidity in the country, they may take their money to the other country. So when the liquidity is transferred to another safe country, the interest spreads in this country are low. In the meantime, the values of $\Delta CoVaR_q^{j|i}$ are negative[2]. For instance, if $\Delta CoVaR_q^{UK|US}$ is negative, the contagion of credit risk did not infect to UK. And UK can be called as a “safe haven” or ”safe harbor” for investors. Not only can a country be seen a safe haven but a financial institution can be. Interest rates are influenced by the risk of default, which occurs when the interest payment is unable or unwilling to pay. For example, as credit risk occurs in the United States, the TED spread increases and investor become more wary to hold risky assest (Brunnermerier) [22].

Santis [23] indicates that during the financial crisis, higher risk aversion will increase the demand of safe haven. And country credit ratings have played a key role in the developments of the spreads for Greece, Ireland, Portugal and Spain. On 5 November 2009 the Greek government revealed a revised budget deficit of 12.7% of GDP for 2009, which was the double of the previous estimate. Since then, the sovereign spreads rose sharply for most of the euro area countries. The factors affecting the sovereign bond yields are associated to aggregate risk, country-specific risk and contagion risk. The aggregate risk is driven by changes in monetary policy, global uncertainty and risk aversion, while the country-specific risk is related to

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[2] When $\hat{\beta}^{j|US}$ is negative, the value of $\Delta CoVaR_{t,q}^{j|US}$ is negative, too. It also means that $CoVaR_{t,q}^{j|US} < CoVaR_{t,50\%}^{j|US}$.

changes in default probabilities on the sovereign debt, the ability to raise fund in the primary market and liquidity factors in the secondary market. Bernanke [24] implies that if landers increase the rate that they charge the borrowers, the higher interest charges will increase the risk of default. Landers do not make loans to some borrowers that they might have lent to in better time. Keeton [25], Stiglitz and Weiss [26], and Devinney [27] provides supply-side equilibrium explanations of credit rationing. In this framework, those who are willing to pay high interest rates may, on average, be a worse risk. They are willing to borrow at high interest rates because they perceive their probability of repaying the loan to be low. Thus, only a risky project which could pay at a high interest rate stays but it defaults more often.

Credit risk cause severe liquidity problems including lender will charge higher interest rate. During times of financial crises, investors seek safe investments into financial market. Even if borrowers provide high interest rate, investors may not male loans to them, and country credit ratings play a key role in these kinds of decisions.

5. Conclusion

In this paper, we focus our attention on the liquidity problem spreads across countries. And we use $CoVaR$ model to capture the risk contagion, even though some countries have no direct linkage. $\Delta CoVaR$ is a measure of systemic risk that extend the measures designed for individual sector.

From the two models, we get the similar findings that: (1) When one country falls into distress, it can cause credit risk spillovers onto other countries. And this is the reason why we put our focus on credit risk contagion not individual risk. (2) Moreover, when liquidity problem occurs in one financial market, the investors may look for more safe investment. For instance, as what we show in this paper, when the United States financial system falls into distress, the contagion of credit risk did not infect to UK. And UK acts like a “safe haven” or “safe harbor” for investors.

Model 1

Table 7: Estimation of CoVaR , Δ CoVaR for 12 European Countries,1999-2012, Measured at 99% quantile, Using Δ IBOR and Contemporaneous TED

$$CoVaR_t^{j|US}(q) = \hat{\alpha}^{j|US} + \hat{\beta}^{j|US} VaR_t^{US}(q) + \hat{\gamma}_1^{j|US} \Delta IBOR_{t-1}^{j} + \hat{\gamma}_2^{j|US} V2TX_{t-1} + \hat{\gamma}_3^{j|US} EUFX_{t-1} + \hat{\gamma}_4^{j|US} STOXX_{t-1} + \hat{\gamma}_5 Gold_{t-1} + \hat{\gamma}_6 Oil_{t-1}$$

$$\Delta CoVaR = CoVaR_t^{j|US}(99\%) - CoVaR_t^{j|US}(50\%) \ , \ VaR_{99\%}^{US} = 2.4013$$

99% quantile regression, parameter estimation: $\Delta IBOR_t^{j} = \alpha^{j|US} + \beta^{j|US} TED_t^{US} + \gamma_1^{j|US} \Delta IBOR_{t-1}^{j} + \gamma_2^{j|US} V2TX_{t-1} + \gamma_3^{j|US} EUFX_{t-1} + \gamma_4^{j|us} STOXX_{t-1} + \gamma_5 Gold_{t-1} + \gamma_6 Oil_{t-1} + \varepsilon_t^{j|US}$

Country j	UK	Germany	France	Portugal	Ireland	Italy	Greece	Spain
Intercept	1.5356***	0.1975***	0.1372***	0.2704***	0.3454***	0.3959***	0.0723*	0.3917***
VaR^{US}_{t}	-0.0426	0.0833	0.0465**	0.1846***	0.1254**	0.0293	0.1001*	0.1131***
$\Delta IBOR^{j}_{t-1}$	0.1849***	-0.2126**	0.1051	0.5905***	0.0294	0.6309***	0.9740***	0.3935***
$V2TX_{t-1}$	0.0033	-0.0128	0.0081*	-0.0177*	-0.0115	-0.0089	-0.0024	0.0006
$EUFX_{t-1}$	0.0969	0.0621	0.0272	-0.0055	0.1049	0.0634	-0.0189	0.0647
$STOXX_{t-1}$	0.0017	-0.0489	0.0180	-0.0867**	-0.0309	-0.0292	0.0182	-0.0355
$Gold_{t-1}$	0.0725**	0.0087	0.0018	-0.0265*	0.0270	-0.0085	-0.0037	0.0140
Oil_{t-1}	-0.0237	0.0031	0.0029	0.0583**	-0.0150	0.0366	0.0153	0.0315**
99% Δ*CoVaR*, year average								
1999	-0.089479	0.175080	0.097805	0.388029	0.263571	0.061646	0.210345	0.237680
2000	-0.089966	0.176033	0.098338	0.390141	0.265006	0.061981	0.211490	0.238974
2001	-0.090523	0.177123	0.098947	0.392557	0.266647	0.062365	0.212799	0.240453
2002	-0.090050	0.176198	0.098429	0.390505	0.265253	0.062039	0.211687	0.239197
2003	-0.089424	0.174973	0.097745	0.387791	0.263410	0.061608	0.210216	0.237534
2004	-0.089451	0.175025	0.097775	0.387907	0.263488	0.061626	0.210279	0.237605
2005	-0.090020	0.176138	0.098396	0.390374	0.265164	0.062018	0.211616	0.239116
2006	-0.089585	0.175288	0.097921	0.388489	0.263884	0.061719	0.210594	0.237962
2007	-0.089192	0.174518	0.097491	0.386783	0.262725	0.061448	0.209670	0.236917
2008	-0.090743	0.177554	0.099187	0.393512	0.267296	0.062517	0.213317	0.241038
2009	-0.089498	0.175119	0.097827	0.388114	0.263629	0.061659	0.210391	0.237732
2010	-0.089705	0.175524	0.098053	0.389011	0.264239	0.061802	0.210877	0.238282
2011	-0.089710	0.175533	0.098058	0.389032	0.264253	0.061805	0.210889	0.238294
2012	-0.089667	0.175448	0.098011	0.388844	0.264125	0.061775	0.210786	0.238179

Notes: The yearly ΔCoVaR measures in this table are the average of daily ΔCoVaR values per year. $\Delta IBOR^{j}_{t-1}$ is the difference between European IBOR and short term deposit interest rate at time *t-1*, and TED^{US}_{t} is the U.S. Treasury Eurodollar spread at time *t*. The state variables at time *t*–1, including $\Delta IBOR^{j}_{t-1}$, the volatility index ($V2TX_{t-1}$), the foreign exchange rate ($EUFX_{t-1}$), the stock index ($STOXX_{t-1}$), the return of West Texas Intermediate crude oil prices (Oil_{t-1}), and returns of Chicago Broad Options Exchange gold price index at time *t-1* ($Gold_{t-1}$).

Table 8: Estimation of CoVaR , △CoVaR for 12 European Countries,1999-2012, Measured at 95% quantile, Using △IBOR and Contemporaneous TED

$$CoVaR_t^{j|US}(q)=\hat{\alpha}^{j|US}+\hat{\beta}^{j|US}VaR_t^{US}(q)+\hat{\gamma}_1^{j|US}\Delta IBOR_{t-1}^{j}+\hat{\gamma}_2^{j|US}V2TX_{t-1}+\hat{\gamma}_3^{j|US}EUFX_{t-1}+\hat{\gamma}_4^{j|US}STOXX_{t-1}+\hat{\gamma}_5Gold_{t-1}+\hat{\gamma}_6Oil_{t-1}$$

$$\Delta CoVaR=CoVaR_t^{j|US}(95\%)-CoVaR_t^{j|US}(50\%)\quad ,VaR_{95\%}^{US}=1.3581$$

95% quantile regression, parameter estimation: $\Delta IBOR_t^j=\alpha^{j|US}+\beta^{j|US}TED_t^{US}+\gamma_1^{j|US}\Delta IBOR_{t-1}^j+\gamma_2^{j|US}V2TX_{t-1}+\gamma_3^{j|US}EUFX_{t-1}+\gamma_4^{j|us}STOXX_{t-1}+\gamma_5Gold_{t-1}+\gamma_6Oil_{t-1}+\varepsilon_t^{j|US}$

Country j	UK	Germany	France	Portugal	Ireland	Italy	Greece	Spain
Intercept	1.1139***	0.0740***	0.0776***	0.1266***	0.1678***	0.1361***	0.0091*	0.1961***
VaR^{US}_t	-0.1911**	0.0315***	0.0071	0.0585***	0.0620***	0.0302	0.0672***	0.0785***
$\Delta IBOR^j_{t-1}$	0.4983***	0.1212***	0.2169***	0.4852***	0.2475***	0.7231***	0.9903***	0.2617***
$V2TX_{t-1}$	-0.0071	0.0018	0.0009	-0.0043	-0.0011	-0.0025	-0.0016*	-0.0046
$EUFX_{t-1}$	-0.2758*	0.0206	-0.0051	-0.0146	0.0143	0.0142	-0.0025	0.0219
$STOXX_{t-1}$	-0.1271*	-0.0069	0.0028	-0.0183	-0.0159	-0.0159	-0.0061**	-0.0290
$Gold_{t-1}$	0.0296	0.0030	0.0022	0.0032	0.0079*	0.0061	0.0021	0.0078
Oil_{t-1}	-0.0077	0.0046	-0.0016	0.0095	-0.0068*	-0.0123*	0.0017	0.0190*
95% Δ*CoVaR*, year average								
1999	-0.201127	0.033137	0.007432	0.061599	0.065275	0.031797	0.070758	0.082651
2000	-0.203214	0.033480	0.007509	0.062239	0.065953	0.032127	0.071493	0.083509
2001	-0.204969	0.033770	0.007574	0.062776	0.066522	0.032404	0.072110	0.084230
2002	-0.204116	0.033629	0.007542	0.062515	0.066245	0.032269	0.071810	0.083880
2003	-0.202654	0.033388	0.007488	0.062067	0.065771	0.032038	0.071296	0.083279
2004	-0.202299	0.033330	0.007475	0.061958	0.065656	0.031982	0.071171	0.083133
2005	-0.203081	0.033458	0.007504	0.062198	0.065909	0.032106	0.071446	0.083454
2006	-0.202838	0.033418	0.007495	0.062123	0.065831	0.032067	0.071360	0.083354
2007	-0.201963	0.033274	0.007463	0.061855	0.065547	0.031929	0.071052	0.082995
2008	-0.206750	0.034063	0.007640	0.063321	0.067100	0.032686	0.072736	0.084962
2009	-0.201632	0.033220	0.007451	0.061754	0.065439	0.031877	0.070936	0.082859
2010	-0.202849	0.033420	0.007496	0.062127	0.065834	0.032069	0.071364	0.083359
2011	-0.202796	0.033411	0.007494	0.062111	0.065817	0.032061	0.071345	0.083337
2012	-0.202990	0.033444	0.007501	0.062170	0.065880	0.032091	0.071414	0.083417

Notes: The yearly ΔCoVaR measures in this table are the average of daily ΔCoVaR values per year. $\Delta IBOR^j_{t-1}$ is the difference between European IBOR and short term deposit interest rate at time *t-1*, and TED^{US}_t is the U.S. Treasury Eurodollar spread at time *t*. The state variables at time *t*–1, including $\Delta IBOR^j_{t-1}$, the volatility index ($V2TX_{t-1}$), the foreign exchange rate ($EUFX_{t-1}$), the stock index ($STOXX_{t-1}$), the return of West Texas Intermediate crude oil prices (Oil_{t-1}), and returns of Chicago Broad Options Exchange gold price index at time *t-1* ($Gold_{t-1}$).

Table 9: Estimation of CoVaR , △CoVaR for 12 European Countries,1999-2012, Measured at 99% quantile, Using TED and Contemporaneous △IBOR

$$CoVaR_t^{US|j}(q) = \hat{\alpha}^{US|j} + \hat{\beta}^{US|j} VaR_t^j(q) + \hat{\gamma}_1^{US|j} TED_{t-1}^{US} + \hat{\gamma}_2^{US|j} VIX_{t-1} + \hat{\gamma}_3^{US|j} USFX_{t-1} + \hat{\gamma}_4^{US|j} SP5_{t-1} + \hat{\gamma}_5 Gold_{t-1} + \hat{\gamma}_6 Oil_{t-1}$$

$$\Delta CoVaR = CoVaR_t^{j|US}(99\%) - CoVaR_t^{j|US}(50\%)$$

99% quantile regression, parameter estimation: $TED_t^{US|j} = \alpha^{US|j} + \beta^{US|j} \Delta IBOR_t^j + \gamma_1^{US|j} TED_{t-1}^{US} + \gamma_2^{US|j} V2TX_{t-1} + \gamma_3^{US|j} EUFX_{t-1} + \gamma_4^{US|j} STOXX_{t-1} + \gamma_5 Gold_{t-1} + \gamma_6 Oil_{t-1} + \varepsilon_t^{US|j}$

Country j	UK	Germany	France	Portugal	Ireland	Italy	Greece	Spain
Intercept	0.0196*	0.0193	0.0135	0.0186	0.0188	0.0172	0.0214***	0.0202*
VaR_t^j	-0.0037	0.0314	0.0662	-0.0691**	-0.0405*	-0.0861	-0.0410***	-0.0675
TED_{t-1}^{US}	1.2620***	1.2660***	1.2723***	1.2616***	1.2695***	1.2637***	1.2637***	1.2636***
VIX_{t-1}	0.0052*	0.0044	0.0053	0.0046*	0.0048*	0.0053	0.0036	0.0065**
$USFX_{t-1}$	0.0677	0.1037	0.0818	0.0606	0.0938	0.0620	0.0743	0.0632
$SP5_{t-1}$	0.0191**	0.0136	0.0162	0.0168	0.0161	0.0160	0.0150	0.0195*
$Gold_{t-1}$	-0.0044	-0.0044	-0.0047	-0.0038	-0.0040	-0.0041	-0.0041	-0.0040
Oil_{t-1}	0.0059	0.0061	0.0056	0.0048	0.0059	0.0051	0.0061	0.0026
99% Δ*CoVaR*, year average								
1999	-0.006205	0.007841	0.009798	-0.027308	-0.016922	-0.051943	-0.017058	-0.031087
2000	-0.006210	0.007918	0.009795	-0.027293	-0.01698	-0.052231	-0.01707	-0.031067
2001	-0.006204	0.008002	0.009869	-0.027782	-0.017087	-0.051726	-0.017176	-0.031567
2002	-0.006209	0.008127	0.010090	-0.027799	-0.017267	-0.050496	-0.017243	-0.031829
2003	-0.006204	0.008078	0.009927	-0.027541	-0.017123	-0.051137	-0.017168	-0.031245
2004	-0.006208	0.008006	0.009896	-0.027339	-0.017071	-0.051472	-0.017115	-0.031135
2005	-0.006200	0.007857	0.009795	-0.027639	-0.016908	-0.051796	-0.017109	-0.031243
2006	-0.006204	0.007961	0.009903	-0.027599	-0.016982	-0.051166	-0.017141	-0.031155
2007	-0.006207	0.008000	0.009975	-0.027533	-0.01707	-0.050894	-0.017153	-0.031302
2008	-0.006213	0.008032	0.009894	-0.027744	-0.017118	-0.051979	-0.017174	-0.031592
2009	-0.006202	0.007967	0.009878	-0.027492	-0.017046	-0.051371	-0.01713	-0.031272
2010	-0.006203	0.007935	0.009834	-0.02764	-0.017006	-0.051768	-0.017134	-0.031363
2011	-0.006211	0.007985	0.009902	-0.027475	-0.017075	-0.05166	-0.017129	-0.031346
2012	-0.006205	0.007950	0.009803	-0.027442	-0.016983	-0.051974	-0.017101	-0.031083

Notes: The yearly ΔCoVaR measures in this table are the average of daily ΔCoVaR values per year. $\Delta IBOR_t^j$ is the difference between European IBOR and short term deposit interest rate at time *t*, and TED_{t-1}^{US} is the U.S. Treasury Eurodollar spread at time *t-1*. The state variables at time *t*–1, including TED_{t-1}^j, the volatility index (VIX_{t-1}), the foreign exchange rate ($USFX_{t-1}$), the stock index ($SP5_{t-1}$), the return of West Texas Intermediate crude oil prices (Oil_{t-1}), and returns of Chicago Broad Options Exchange gold price index at time *t-1* ($Gold_{t-1}$)

Table 10: Estimation of CoVaR , ΔCoVaR for 12 European Countries,1999-2012, Measured at 95% quantile, Using ΔIBOR and Contemporaneous TED

$$CoVaR_t^{US|j}(q) = \hat{\alpha}^{US|j} + \hat{\beta}^{US|j} VaR_t^j(q) + \hat{\gamma}_1^{US|j} TED_{t-1}^{US} + \hat{\gamma}_2^{US|j} VIX_{t-1} + \hat{\gamma}_3^{US|j} USFX_{t-1} + \hat{\gamma}_4^{US|j} SP5_{t-1} + \hat{\gamma}_5 Gold_{t-1} + \hat{\gamma}_6 Oil_{t-1}$$

$$\Delta CoVaR = CoVaR_t^{j|US}(95\%) - CoVaR_t^{j|US}(50\%)$$

95% quantile regression, parameter estimation: $TED_t^{US|j} = \alpha^{US|j} + \beta^{US|j} \Delta IBOR_t^j + \gamma_1^{US|j} TED_{t-1}^{US} + \gamma_2^{US|j} V2TX_{t-1} + \gamma_3^{US|j} EUFX_{t-1} + \gamma_4^{US|j} STOXX_{t-1} + \gamma_5 Gold_{t-1} + \gamma_6 Oil_{t-1} + \varepsilon_t^{US|j}$

Country j	UK	Germany	France	Portugal	Ireland	Italy	Greece	Spain
Intercept	0.0106**	0.0125***	0.0130***	0.0146***	0.0124***	0.0140***	0.0145***	0.0132***
VaR^j_t	0.0056	0.0057	0.0335	-0.0488***	-0.0053	-0.0385**	-0.0214	-0.0035
TED^{US}_{t-1}	1.0966***	1.0947***	1.0936***	1.0923***	1.0955***	1.0927***	1.0970***	1.0941***
VIX_{t-1}	0.0007	0.0009	0.0014	0.0012	0.0011	0.0014	0.0008	0.0014
$USFX_{t-1}$	0.0188	0.0197	0.0149	0.0126	0.0171	0.0180	0.0126	0.0172
$SP5_{t-1}$	0.0020	0.0025	0.0035	0.0053	0.0031	0.0062	0.0030	0.0034
$Gold_{t-1}$	0.0006	0.0004	0.0005	0.0006	0.0004	0.0005	0.0006	0.0005
Oil_{t-1}	0.0000	-0.0003	-0.0003	0.0000	0.0001	0.0003	-0.0010	0.0001
95% $\Delta CoVaR$, year average								
1999	0.007783	0.000618	0.002344	-0.010036	-0.001098	-0.006008	-0.008172	-0.000778
2000	0.007764	0.000616	0.002337	-0.010023	-0.001101	-0.005995	-0.008172	-0.00078
2001	0.007774	0.000621	0.002327	-0.010119	-0.001104	-0.006016	-0.008166	-0.000794
2002	0.007812	0.000626	0.002333	-0.010166	-0.001105	-0.006127	-0.008186	-0.000801
2003	0.007754	0.000621	0.002317	-0.010143	-0.001101	-0.006018	-0.008196	-0.000787
2004	0.007769	0.000619	0.002331	-0.010084	-0.001101	-0.006029	-0.00819	-0.000783
2005	0.007759	0.000619	0.00233	-0.010069	-0.001099	-0.005972	-0.008168	-0.000782
2006	0.007737	0.00062	0.00232	-0.010071	-0.001098	-0.005989	-0.00819	-0.000781
2007	0.007772	0.000622	0.00233	-0.010089	-0.0011	-0.006051	-0.008192	-0.000785
2008	0.007766	0.000619	0.00233	-0.010057	-0.001106	-0.006027	-0.008161	-0.000795
2009	0.007782	0.000621	0.002332	-0.010122	-0.0011	-0.006027	-0.008183	-0.000785
2010	0.007769	0.00062	0.00233	-0.010092	-0.001101	-0.006	-0.008169	-0.000787
2011	0.00778	0.000619	0.002337	-0.010059	-0.001103	-0.006043	-0.008175	-0.000787
2012	0.007745	0.000617	0.002325	-0.010062	-0.0011	-0.005972	-0.008178	-0.000781

Notes: The yearly ΔCoVaR measures in this table are the average of daily ΔCoVaR values per year. $\Delta IBOR^j_t$ is the difference between European IBOR and short term deposit interest rate at time *t*, and TED^{US}_{t-1} is the U.S. Treasury Eurodollar spread at time *t-1*. The state variables at time *t*–1, including TED^j_{t-1}, the volatility index (VIX_{t-1}), the foreign exchange rate ($USFX_{t-1}$), the stock index ($SP5_{t-1}$), the return of West Texas Intermediate crude oil prices (Oil_{t-1}), and returns of Chicago Broad Options Exchange gold price index at time *t-1* ($Gold_{t-1}$).

Model 2

Table 11: Estimation of CoVaR , △CoVaR for 12 European Countries,1999-2012, Measured at 99% quantile, Using △IBOR and Lagged TED

$$CoVaR_t^{j|US}(q) = \hat{\alpha}^{j|US} + \hat{\beta}^{j|US} VaR_{t-1}^{US}(q) + \hat{\gamma}_1^{j|US} \Delta IBOR_{t-1}^{j} + \hat{\gamma}_2^{j|US} V2TX_{t-1} + \hat{\gamma}_3^{j|US} EUFX_{t-1} + \hat{\gamma}_4^{j|US} STOXX_{t-1} + \hat{\gamma}_5 Gold_{t-1} + \hat{\gamma}_6 Oil_{t-1}$$

$$\Delta CoVaR = CoVaR_t^{j|US}(99\%) - CoVaR_t^{j|US}(50\%), \quad VaR_{99\%}^{US} = 2.4845$$

99% quantile regression, parameter estimation: $\Delta IBOR_t^j = \alpha^{j|US} + \beta^{j|US} TED_{t-1}^{US} + \gamma_1^{j|US} \Delta IBOR_{t-1}^{j} + \gamma_2^{j|US} V2TX_{t-1} + \gamma_3^{j|US} EUFX_{t-1} + \gamma_4^{j|us} STOXX_{t-1} + \gamma_5 Gold_{t-1} + \gamma_6 Oil_{t-1} + \varepsilon_t^{j|US}$

Country j	UK	Germany	France	Portugal	Ireland	Italy	Greece	Spain
Intercept	1.5352***	0.1988***	0.1380***	0.2668***	0.3439***	0.3965***	0.0731*	0.3911***
VaR^{US}_{t-1}	-0.0402	0.0796*	0.0481***	0.2006***	0.1329***	0.0268	0.1042**	0.1087
$\Delta IBOR^{j}_{t-1}$	0.1848***	-0.2122**	0.1155	0.5847***	0.0218	0.6318***	0.9724***	0.3992***
$V2TX_{t-1}$	0.0039	-0.0127	0.0084*	-0.0180*	-0.0115	-0.0089	-0.0029	0.0001
$EUFX_{t-1}$	0.0979	0.0600	0.0286	-0.0112	0.1047*	0.0647	-0.0205	0.0629
$STOXX_{t-1}$	0.0033	-0.0486	0.0219	-0.0877***	-0.0311	-0.0295	0.0144	-0.0319
$Gold_{t-1}$	0.0722**	0.0085	0.0011	-0.0238*	0.0270**	-0.0085	-0.0035	0.0136
Oil_{t-1}	-0.0205	0.0028	0.0040	0.0550***	-0.0154	0.0365*	0.0164	0.0328**
99% Δ*CoVaR*, year average								
1999	-0.084445	0.167421	0.101099	0.421734	0.279259	0.056432	0.218930	0.228481
2000	-0.084870	0.168263	0.101608	0.423855	0.280664	0.056716	0.220031	0.229631
2001	-0.085435	0.169383	0.102284	0.426675	0.282531	0.057093	0.221495	0.231159
2002	-0.084945	0.168413	0.101698	0.424233	0.280914	0.056766	0.220227	0.229835
2003	-0.084403	0.167338	0.101049	0.421524	0.279120	0.056404	0.218821	0.228368
2004	-0.084428	0.167387	0.101079	0.421648	0.279203	0.056421	0.218886	0.228435
2005	-0.084900	0.168324	0.101644	0.424007	0.280765	0.056736	0.220110	0.229713
2006	-0.084540	0.167610	0.101213	0.422209	0.279574	0.056496	0.219177	0.228739
2007	-0.084153	0.166842	0.100750	0.420276	0.278294	0.056237	0.218173	0.227692
2008	-0.085675	0.169858	0.102571	0.427874	0.283325	0.057254	0.222117	0.231808
2009	-0.084388	0.167307	0.101030	0.421446	0.279069	0.056394	0.218781	0.228326
2010	-0.084651	0.167830	0.101346	0.422764	0.279941	0.056570	0.219465	0.229040
2011	-0.084640	0.167808	0.101333	0.422708	0.279904	0.056562	0.219436	0.229009
2012	-0.084601	0.167730	0.101286	0.422511	0.279774	0.056536	0.219334	0.228903

Notes: The yearly ΔCoVaR measures in this table are the average of daily ΔCoVaR values per year. $\Delta IBOR^{j}_{t}$ is the difference between European IBOR and short term deposit interest rate at time *t*, and TED^{US}_{t-1} is the U.S. Treasury Eurodollar spread at time *t*-1. The state variables at time *t*–1, including $\Delta IBOR^{j}_{t-1}$, the volatility index ($V2TX_{t-1}$), the foreign exchange rate ($EUFX_{t-1}$), the stock index ($STOXX_{t-1}$), the return of West Texas Intermediate crude oil prices (Oil_{t-1}), and returns of Chicago Broad Options Exchange gold price index at time *t-1* ($Gold_{t-1}$).

Table 12: Estimation of CoVaR , △CoVaR for 12 European Countries,1999-2012, Measured at 95% quantile, Using △IBOR and Lagged TED

$$CoVaR_t^{j|US}(q) = \hat{\alpha}^{j|US} + \hat{\beta}^{j|US} VaR_{t-1}^{US}(q) + \hat{\gamma}_1^{j|US} \Delta IBOR_{t-1}^{j} + \hat{\gamma}_2^{j|US} V2TX_{t-1} + \hat{\gamma}_3^{j|US} EUFX_{t-1} + \hat{\gamma}_4^{j|US} STOXX_{t-1} + \hat{\gamma}_5 Gold_{t-1} + \hat{\gamma}_6 Oil_{t-1}$$

$$\Delta CoVaR = CoVaR_t^{j|US}(95\%) - CoVaR_t^{j|US}(50\%), \quad VaR_{95\%}^{US} = 1.4384$$

95% quantile regression, parameter estimation: $\Delta IBOR_t^j = \alpha^{j|US} + \beta^{j|US} TED_{t-1}^{US} + \gamma_1^{j|US} \Delta IBOR_{t-1}^{j} + \gamma_2^{j|US} V2TX_{t-1} + \gamma_3^{j|US} EUFX_{t-1} + \gamma_4^{j|us} STOXX_{t-1} + \gamma_5 Gold_{t-1} + \gamma_6 Oil_{t-1} + \varepsilon_t^{j|US}$

Country j	UK	Germany	France	Portugal	Ireland	Italy	Greece	Spain
Intercept	1.1060***	0.0734***	0.0791***	0.1268***	0.1665***	0.1368***	0.0090	0.1951***
VaR^{US}_{t-1}	-0.1607*	0.0306*	0.0038	0.0617***	0.0652***	0.0301	0.0685***	0.0838***
$\Delta IBOR^{j}_{t-1}$	0.4971***	0.1181***	0.2163***	0.4749***	0.2496***	0.7191***	0.9864***	0.2653***
$V2TX_{t-1}$	-0.0080	0.0021	0.0006	-0.0040	-0.0011	-0.0026	-0.0009	-0.0035
$EUFX_{t-1}$	-0.2994**	0.0217	-0.0044	-0.0156	0.0171	0.0139	-0.0021	0.0263
$STOXX_{t-1}$	-0.1307*	-0.0056	0.0023	-0.0172	-0.0162	-0.0156	-0.0039	-0.0275
$Gold_{t-1}$	0.0300	0.0031	0.0021	0.0024	0.0073*	0.0063	0.0025	0.0076
Oil_{t-1}	-0.0015	0.0052	-0.0019	0.0101	-0.0072*	-0.0118	0.0021	0.0177*
95% Δ*CoVaR*, year average								
1999	-0.169082	0.032193	0.004034	0.064924	0.068570	0.056432	0.218930	0.088186
2000	-0.170817	0.032523	0.004075	0.065590	0.069273	0.056716	0.220031	0.089090
2001	-0.172476	0.032839	0.004115	0.066227	0.069946	0.057093	0.221495	0.089956
2002	-0.171468	0.032647	0.004091	0.065840	0.069538	0.056766	0.220227	0.089430
2003	-0.170349	0.032434	0.004064	0.065411	0.069084	0.056404	0.218821	0.088847
2004	-0.170121	0.032391	0.004059	0.065323	0.068991	0.056421	0.218886	0.088728
2005	-0.170616	0.032485	0.004071	0.065513	0.069192	0.056736	0.220110	0.088986
2006	-0.170521	0.032467	0.004068	0.065477	0.069154	0.056496	0.219177	0.088936
2007	-0.169751	0.032320	0.004050	0.065181	0.068841	0.056237	0.218173	0.088535
2008	-0.174159	0.033159	0.004155	0.066874	0.070629	0.057254	0.222117	0.090833
2009	-0.169163	0.032208	0.004036	0.064955	0.068603	0.056394	0.218781	0.088228
2010	-0.170501	0.032463	0.004068	0.065469	0.069145	0.056570	0.219465	0.088926
2011	-0.170490	0.032461	0.004068	0.065465	0.069141	0.056562	0.219436	0.088920
2012	-0.170621	0.032486	0.004071	0.065515	0.069194	0.056536	0.219334	0.088988

Notes: The yearly ΔCoVaR measures in this table are the average of daily ΔCoVaR values per year. $\Delta IBOR^{j}_{t}$ is the difference between European IBOR and short term deposit interest rate at time *t*, and TED^{US}_{t-1} is the U.S. Treasury Eurodollar spread at time *t-1*. The state variables at time *t*–1, including $\Delta IBOR^{j}_{t-1}$, the volatility index ($V2TX_{t-1}$), the foreign exchange rate ($EUFX_{t-1}$), the stock index ($STOXX_{t-1}$), the return of West Texas Intermediate crude oil prices (Oil_{t-1}), and returns of Chicago Broad Options Exchange gold price index at time *t-1* ($Gold_{t-1}$).

Table 13: Estimation of CoVaR , △CoVaR for 12 European Countries,1999-2012, Measured at 99% quantile, Using △IBOR and Lagged TED

$$CoVaR_t^{US|j}(q) = \hat{\alpha}^{US|j} + \hat{\beta}^{US|j} VaR_{t-1}^{j}(q) + \hat{\gamma}_1^{US|j} TED_{t-1}^{US} + \hat{\gamma}_2^{US|j} VIX_{t-1} + \hat{\gamma}_3^{US|j} USFX_{t-1} + \hat{\gamma}_4^{US|j} SP5_{t-1} + \hat{\gamma}_5 Gold_{t-1} + \hat{\gamma}_6 Oil_{t-1}$$

$$\Delta CoVaR = CoVaR_t^{j|US}(99\%) - CoVaR_t^{j|US}(50\%)$$

99% quantile regression, parameter estimation: $TED_t^{US|j} = \alpha^{US|j} + \beta^{US|j}\Delta IBOR_{t-1}^{j} + \gamma_1^{US|j} TED_{t-1}^{US} + \gamma_2^{US|j} V2TX_{t-1} + \gamma_3^{US|j} EUFX_{t-1} + \gamma_4^{US|j} STOXX_{t-1} + \gamma_5 Gold_{t-1} + \gamma_6 Oil_{t-1} + \varepsilon_t^{US|j}$

Country j	UK	Germany	France	Portugal	Ireland	Italy	Greece	Spain
Intercept	0.0067	0.0188*	0.0162	0.0196	0.0172*	0.0175	0.0232	0.0151*
VaR^{US}_{t-1}	0.0118	0.0168	0.0428	-0.0893**	-0.0566*	-0.0705	-0.0500	0.0370
TED^{US}_{t-1}	1.2784***	1.2637***	1.2640***	1.2630***	1.2723***	1.2663***	1.2741***	1.2665***
VIX_{t-1}	0.0037	0.0049	0.0048	0.0040	0.0042	0.0052	0.0035	0.0049*
$USFX_{t-1}$	0.0566	0.0951	0.0854	0.0855	0.0880	0.0914	0.0678	0.0836*
$SP5_{t-1}$	0.0081	0.0141	0.0140	0.0123	0.0146	0.0132	0.0157	0.0158
$Gold_{t-1}$	-0.0062	-0.0039	-0.0041	-0.0041	-0.0048	-0.0044	-0.0061	-0.0038
Oil_{t-1}	0.0038	0.0063	0.0053	0.0057	0.0049	0.0050	0.0040	0.0054
99% Δ*CoVaR*, year average								
1999	0.019641	0.004180	0.006358	-0.035437	-0.023536	-0.042311	-0.020812	0.017048
2000	0.019655	0.004242	0.006337	-0.035277	-0.023685	-0.042757	-0.020816	0.017020
2001	0.019637	0.004284	0.006378	-0.035934	-0.023819	-0.042397	-0.020944	0.017291
2002	0.019654	0.004353	0.006528	-0.035894	-0.024082	-0.041337	-0.021021	0.017426
2003	0.019636	0.004328	0.006417	-0.035558	-0.023894	-0.041928	-0.020930	0.017117
2004	0.019646	0.004289	0.006403	-0.035396	-0.023809	-0.042109	-0.020880	0.017074
2005	0.019626	0.004210	0.006343	-0.035712	-0.023588	-0.042365	-0.020864	0.017116
2006	0.019638	0.004262	0.006407	-0.035685	-0.023682	-0.041887	-0.020903	0.017073
2007	0.019648	0.004284	0.006452	-0.035576	-0.023808	-0.041685	-0.020914	0.017148
2008	0.019665	0.004299	0.006378	-0.035883	-0.023843	-0.042736	-0.020936	0.017285
2009	0.019630	0.004275	0.006417	-0.035535	-0.023818	-0.041846	-0.020902	0.017165
2010	0.019634	0.004249	0.006363	-0.035732	-0.023719	-0.042385	-0.020894	0.017189
2011	0.019659	0.004280	0.006406	-0.035500	-0.023827	-0.042308	-0.020887	0.017176
2012	0.019640	0.004257	0.006344	-0.035498	-0.023682	-0.042512	-0.020858	0.017032

Notes: The yearly ΔCoVaR measures in this table are the average of daily ΔCoVaR values per year. $\Delta IBOR^{j}_{t}$ is the difference between European IBOR and short term deposit interest rate at time *t*, and TED^{US}_{t-1} is the U.S. Treasury Eurodollar spread at time *t*-1. The state variables at time *t*–1, including TED^{j}_{t-1}, the volatility index (VIX_{t-1}), the foreign exchange rate ($USFX_{t-1}$), the stock index ($SP5_{t-1}$), the return of West Texas Intermediate crude oil prices (Oil_{t-1}), and returns of Chicago Broad Options Exchange gold price index at time *t-1* ($Gold_{t-1}$).

Table 14: Estimation of CoVaR , △CoVaR for 12 European Countries,1999-2012, Measured at 95% quantile, Using △IBOR and Lagged TED

$$CoVaR_t^{US|j}(q) = \hat{\alpha}^{US|j} + \hat{\beta}^{US|j} VaR_t^j(q) + \hat{\gamma}_1^{US|j} TED_{t-1}^{US} + \hat{\gamma}_2^{US|j} VIX_{t-1} + \hat{\gamma}_3^{US|j} USFX_{t-1} + \hat{\gamma}_4^{US|j} SP5_{t-1} + \hat{\gamma}_5 Gold_{t-1} + \hat{\gamma}_6 Oil_{t-1}$$

$$\Delta CoVaR = CoVaR_t^{j|US}(95\%) - CoVaR_t^{j|US}(50\%)$$

95% quantile regression, parameter estimation: $TED_t^{US|j} = \alpha^{US|j} + \beta^{US|j} \Delta IBOR_{t-1}^j + \gamma_1^{US|j} TED_{t-1}^{US} + \gamma_2^{US|j} V2TX_{t-1} + \gamma_3^{US|j} EUFX_{t-1} + \gamma_4^{US|j} STOXX_{t-1} + \gamma_5 Gold_{t-1} + \gamma_6 Oil_{t-1} + \varepsilon_t^{US|j}$

Country j	UK	Germany	France	Portugal	Ireland	Italy	Greece	Spain
Intercept	0.0092***	0.0121	0.0122***	0.0141***	0.0140***	0.0139***	0.0143***	0.0130***
VaR^j_{t-1}	0.0133***	-0.0127***	0.0130	-0.0413***	-0.0314**	-0.0388***	-0.0215***	-0.0156
TED^{US}_{t-1}	1.1020***	1.0947	1.0944***	1.0911***	1.0948***	1.0921***	1.0970***	1.0938***
VIX_{t-1}	0.0005	0.0008	0.0014	0.0008	0.0012	0.0011	0.0008	0.0015
$USFX_{t-1}$	0.0144	0.0193	0.0201	0.0161	0.0190	0.0139	0.0135	0.0174
$SP5_{t-1}$	0.0001	0.0019	0.0048	0.0027	0.0041	0.0037	0.0023	0.0055
$Gold_{t-1}$	0.0004	0.0005	0.0003	0.0006	0.0005	0.0005	0.0006	0.0002
Oil_{t-1}	-0.0004	-0.0002	0.0000	0.0005	0.0001	0.0006	-0.0009	0.0002
95% $\Delta CoVaR$, year average								
1999	0.018294	-0.001394	0.000911	-0.008482	-0.006517	-0.006060	-0.008223	-0.003442
2000	0.018266	-0.001389	0.000909	-0.008492	-0.006540	-0.006051	-0.008223	-0.003457
2001	0.018279	-0.001399	0.000904	-0.008567	-0.006556	-0.006064	-0.008215	-0.003521
2002	0.018383	-0.001411	0.000907	-0.008609	-0.006562	-0.006186	-0.008237	-0.003551
2003	0.018254	-0.001399	0.000902	-0.008594	-0.006540	-0.006077	-0.008245	-0.003493
2004	0.018276	-0.001396	0.000906	-0.008547	-0.006536	-0.006083	-0.008239	-0.003474
2005	0.018258	-0.001396	0.000906	-0.008528	-0.006524	-0.006032	-0.008220	-0.003467
2006	0.018205	-0.001397	0.000902	-0.008531	-0.006523	-0.006045	-0.008240	-0.003463
2007	0.018289	-0.001401	0.000906	-0.008544	-0.006532	-0.006108	-0.008242	-0.003481
2008	0.018243	-0.001393	0.000905	-0.008512	-0.006572	-0.006059	-0.008208	-0.003521
2009	0.018338	-0.001403	0.000907	-0.008587	-0.006532	-0.006107	-0.008237	-0.003490
2010	0.018284	-0.001397	0.000906	-0.008547	-0.006540	-0.006058	-0.008219	-0.003491
2011	0.018309	-0.001396	0.000909	-0.008523	-0.006551	-0.006102	-0.008225	-0.003492
2012	0.018219	-0.001391	0.000904	-0.008525	-0.006533	-0.006027	-0.008229	-0.003463

Notes: The yearly ΔCoVaR measures in this table are the average of daily ΔCoVaR values per year. $\Delta IBOR^j_t$ is the difference between European IBOR and short term deposit interest rate at time *t*, and TED^{US}_{t-1} is the U.S. Treasury Eurodollar spread at time *t-1*. The state variables at time *t*–1, including TED^j_{t-1}, the volatility index (VIX_{t-1}), the foreign exchange rate ($USFX_{t-1}$), the stock index ($SP5_{t-1}$), the return of West Texas Intermediate crude oil prices (Oil_{t-1}), and returns of Chicago Broad Options Exchange gold price index at time *t-1* ($Gold_{t-1}$).

References

[1] Allen F., Babus A. and Carletti C., "Asset Commonality, Debt Maturity and Systemic Risk", Journal of Financial Economics, Vol.104, No. 3, pp. 519-534, 2012.

[2] Herring R. and Wachter S., "Bubbles in Real Estate Markets", Zell/Lurie Real Estate Center Working Paper, 2003.

[3] Reinhart C.M. and Rogoff K.S., "On Graduation from Default, Inflation and Banking Crises: Elusive or Illusion?", NBER Macroeconomics Annual ,Vol. 25, No. 1 , pp. 1-36, 2010.

[4] Brunnermeier M.K., Crocket A., Goodhart C.,Perssaud A.D., and Shin H., "The Fundamental Principles of Financial Regulation", Geneva Report on the World Economy ,Vol. 11, 2009.

[5] Diamond D.W. and Rajan R.G., "Fear of Fire Sales, Illiquidity Seeking, and Credit Freezes", Quarterly Journal of Economics, Vol. 126, No. 2, pp. 557-591, 2011.

[6] Allen F. and Gale D., "Financial contagion", Vol. 108, Issue 1, pp. 1-33, Journal of political economy, 2000.

[7] Longstaff F.A., "The Subprime Credit Crisis and Contagion in Fnancial Markets", Journal of Financial Economics , 97, pp. 436-450, 2010.

[8] Koenker R. and Bassett G., "Regression Quantiles", Econometrica: Journal of the Econometric Society, Vol. 46, No. 1, pp. 33-50, 1978.

[9] Jorion P., Value at Risk : the New Benchmark for Managing Financial Risk (3rd), New York, McGraw-Hill,2007.

[10] Kupiec P., Risk Management: Value at Risk and Beyond, Cambridge Univesity Press, New York, 2002.

[11] Adrian T. and Brunnermeier M.K.," CoVaR" , NBER Working Paper , No. 17454, 2011.

[12] Billio M., Getmansky M., Lo AW, Pelizzon L., "Econometric Measures of Connectedness and Systemic Risk in the Finance and Insurance Sectors", Journal of Financial Economics, Vol. 104, No. 3, PP. 535 – 559, 2012.

[13] Lehar A., Gauthier C., and Souissi M., "Macroprudential Capital Requirements and Systemic Risk", Journal of Financial Intermediation, Vol. 21, No. 4, pp. 594 – 618, 2012.

[14] Taleb N. N., The Black Swan, Random House, United States, 2007.

[15] Longstaff F.A., "The Subprime Credit Crisis and Contagion in Financial Markets", Journal of Financial Economics, Vol. 97, No. 3, pp. 436-450, 2010.

[16] Melvin M. and Taylor M.P., The Crisis in the Foreign Exchange Market, Journal of International Money and Finance, Vol. 28, pp.1317-1330, 2009.

[17] Kodres L.E. and Pritsker M., "A Rational Expectations Model of Financial Contagion", The Journal of Finance, Vol. 57, No. 2, pp. 769-799, 2002.

[18] Brunnermeier M.K. and Pedersen L.H., "Market Liquidity and Funding Liquidity", Review of Financial Studies, Vol. 22, No. 6, pp. 2201-2238, 2009.

[19] Brunnermeier M.K., Deciphering the liquidity and credit crunch 2007-08, Working Paper, 2008.

[20] Diamond D.W. and Rajan R.G., "Liquidity Shortages and Banking Crises", Journal of Finance, Vol. 60, No. 2, pp. 615-647, 2005.

[21] Engle R.F. and Manganelli S., "CAViaR: conditional autoregressive value at risk by regression quantiles", Journal of Business & Economic Statistics,Vol. 22, No. 4, pp.367-381, 2004.

[22] Brunnermerier M.K., "Deciphering the Liquidity and Credit Crunch 2007-08", NBER Working Paper , No. 14612, 2008.

[23] Santis R.De., "The Euro Area Sovereign Debt Crisis: Safe Haven, Credit Rating Agencies and the Spread of the Fever from Greece, Ireland and Portugal", ECB Working Paper, No. 1419 , 2012.

[24] Bernanke B.S., "Irreversibility, uncertainty, and cyclical investment", The Quarterly Journal of Economics, 98 (1), PP. 85-106, 1983.

[25] Keeton W.R., Equilibrium credit rationing, Garland, New York, 1979.

[26] Stiglitz J.E. and Weiss A., "Credit Rationing in Markets with Imperfect Information ", American economic Review, Vol. 71, No. 3, 1981.

[27] Kugler P., "Credit rationing and the adjustment of the loan rate: An empirical investigation", Journal of Macroeconomics, Vol. 9, No. 4, pp. 505-525, 1987.