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# Document de Travail
## Working Paper
## 2014-24

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The impact of the global and eurozone crises on European banks stocks
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Abstract

This paper analyzes the influence of successive crises, including the recent European sovereign debt crisis, on banks' equity returns for 11 countries. Our data span the period December 14th 2007-March 8th 2013 that encompasses different episodes of economic and financial turmoil since the collapse of the subprime credit market. Our contribution to the literature is twofold. First, we use an explicit multifactor model of equity returns extended with a sovereign risk factor. Second, we adopt a Smooth Transition Regression (STR) framework that allows for an endogenous definition of crisis periods and captures the changes in parameters associated with shift contagion. We find that contagion from the European sovereign debt crisis to banks' equity returns has been confined to eurozone banks, whereas U.S. banks' equity returns were unharmed by its direct impact and may even have benefited from a kind of flight to quality effect. Besides, across banks from the euro area, German financial institutions have not been completely spared by the eurozone debt crisis, though they have been relatively less affected.

Key words: Smooth Transition Regression model, European sovereign debt crisis, Banks' equity returns, Contagion, Interdependence.

JEL Code: E6; F3; G2

1. Introduction

The 2007-2009 crisis began by intense tensions in the financial systems of advanced economies and unraveled into a dramatic contraction in global growth. To prevent a larger collapse in economic activity, governments and central banks intervened massively in order to support aggregate demand –via automatic stabilizers and discretionary expenditures- and to bailout financial institutions. As a result, public finance experienced a marked degradation, leading to the emergence of the euro area sovereign debt crisis as a new phase of the global crisis.[1] According to the IMF Fiscal Monitor, the fiscal deficit in advanced countries[2] moved from 1.3% of the GDP in 2006 to 8.9% in 2009, while the public debt in percentage of the GDP climbed from 75.8 to 93.7 over the same period. The degradation in public finance has been more dramatic in the eurozone, and more specifically in its peripheral countries. Thus, the average fiscal deficit in Greece, Ireland, Italy, Portugal, and Spain (GIIPS-group) increased from 1.6% of the GDP in 2006 to 11.2% in 2009, while their public debt surged from 68.4% to 89.6%. It is important to stress that, while advanced countries have succeed to stabilize their public debt after 2012, IMF projections suggest

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[1] For an overview, see Brender et al. (2013).
[2] Advanced countries include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, the Netherlands, Portugal, Spain, the United Kingdom, and the United Sates.

that public debt in GIIPS should continue to grow until 2014 (with a projected peak at 130.5 percent of the GDP).

Any drop in the market value of European sovereign debt has a negative impact on the balance sheets of European banks. Banks hold large amounts of government bonds to satisfy multiple purposes. First, investing in government bonds allows financial institutions to diversify their portfolio into low risk assets. The European prudential regulation has encouraged banks to hold such "safe" and liquid securities that may help to cushion losses on riskier assets. Second, holding government bonds is crucial for banks to access the central bank liquidity, insofar as the refinancing operations of the central bank are based on highly rated securities. Besides, interbank loans and repos rely heavily on the use of public bonds as collaterals. Therefore, when the value of sovereign bonds plummets it reduces both the market value of these assets in banks' balance sheets and banks' access to funding. These large holdings of eurozone government bonds by European banks have led to a growing concern about possible spillovers from the sovereigns to the banks and a second round of spillovers from banks to sovereigns. Caruana and Avdjiev (2012) identify various channels of transmission between banks and sovereigns. The transmission of financial sector risks to sovereigns that fuelled the Greek and eurozone sovereign debt crisis in 2010-2011 rests on two main mechanisms. On the one hand, the deterioration in the balance sheets of financial institutions may cause a credit crunch that impinges on consumption and investment, and, in turn, spurs a slowdown in economic activity. As a result tax revenues decrease, leading to deterioration in the fiscal situation of the state. On the other hand, the authorities may be in the obligation to support systematically important financial institutions against the threat of bankruptcy. Concerning the transmission of sovereign risks to the financial sector, which is more the focus of this paper, Caruana and Avdjiev (2012) stress first the impact of banks' direct portfolio exposures. The Committee on the Global Finance System estimates that, for a sample of 21 advanced economies[3] at the end-2010, the banks' exposures to the domestic sovereign, measured as a percentage of banks' equities, have been above 30 percent in all countries except Austria, Ireland, and the United Kingdom (CGFS, 2011). On average, 85 percent of this exposure is held in the banking book. It is important to stress that the holding of government bonds is characterized by a strong home bias. Second, as sovereign bonds are used by banks as collaterals, a decrease in the quality of government debt may lead to a significant deterioration of funding conditions for financial institutions. Figure A1a in appendix exhibits the relationship between the stress in the eurozone interbank markets and the developments of the European sovereign debt crisis (Figure A1a) on the one hand, and between these latter and the banks credit default swaps (Figure A1b).[4] Interestingly, Figure A1b suggests some impact of the eurozone crisis on the United Kingdom and the United States. A third channel of transmission from sovereigns to banks resides in the fact that a marked increase in sovereign credit risk may trigger doubts on the ability of the governments to offer a credible guarantee to banks and / or financial supports in case of distress. In other terms a sovereign domestic debt crisis decreases the value of the explicit and implicit

[3] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Luxembourg, the Netherlands, Poland, Portugal, Slovenia, Sweden, Spain, Switzerland, the United Kingdom, and the United States.

[4] See also CGFS (2011) and van Rixtel and Gasperini (2013).

government guarantees that benefit banks that are considered too big or too interconnected (TBTF) to be allowed to fail. As these guarantees amount to very significant government subsidies (Schich and Lindh, 2012) their impairment may have a large negative impact on TBTF banks' balance sheets.

The European sovereign debt crisis has led to a growing literature. A first strand analyses contagion across sovereign bonds (yield spreads and / or CDS spreads). Mixed results emerge from this literature. For example, while Beirne and Fratzscher (2013) find evidence of contagion, Caporin et al. (2013) conclude that co-movements during extreme conditions do not exhibit evidence of contagion. A second strand of the literature focuses on the influence of the financial sector on sovereign CDS. Such a literature stresses the presence of a private-to-public risk transfer. More specifically, Acharya et al. (2013) find that in the pre-bailout period –that is before the announcement of the bailout in Ireland in late September 2008- no clear relationship between bank and sovereign CDS is identified. The situation changes in the aftermath of the bailouts. In a similar way, Mody and Sandri (2012) consider that the nationalization of Anglo-Irish in January 2009 has played a decisive role to the increase in the sensitivity of the sovereign's spread to the weakness of the financial sector.[5] Gerlach et al. (2010) and Dieckmann and Plank (2012) conclude that the size of the domestic financial sector exerts an influence on the responses of the sovereign's spreads to financial tensions. A third strand of the literature finds that the quality of the sovereign debt influences the financial sector. For instance, Bolton and Jeanne (2011) show that the holding of sovereign bonds by banks tends to exacerbate contagion effects. Such effects are particularly important in a monetary union such as the eurozone insofar as the integration of the banking system reduces the home bias that usually characterizes these holdings.

This paper contributes to the growing literature on the European sovereign debt crisis by focusing on the impact of the successive crises on banks' equity returns over the period 2007-2013. Whereas most papers of the related literature do not rely on an explicit theoretical model of stock returns, we start from a variant of the multifactor model of Fama and French, extended by Carhart (1997), to control for the different channels of risk transmission to banks' stocks. More specifically, we modify the four-factor model of Carhart (1997) in two ways. First, we add the sovereign risk factor – proxied by the sovereign CDS - as an explanatory variable of banks' equity returns. Second, we adopt a nonlinear specification to account for the nonlinearities and, more specifically the shift contagion (Forbes and Rigobon, 2001) that may derive from the successive crisis episodes. So far the literature on the consequences of the European sovereign debt crisis for the banking sector has mainly captured these nonlinearities through dummy variables associated to crisis periods or to extreme events. In this paper, we use a Smooth Transition Regression (STR) framework that allows for an endogenous definition of crisis periods, smooth transitions and captures the shifts in parameters associated with shift contagion. We choose the VSTOXX – the implied volatility of the Eurostoxx50 - as the transition variable insofar as it represents crisis

[5] The authors show that the failure of Bear Stearns in March 2008 has been a first turning point.

episodes in the eurozone stock market. We estimate this model for a sample of 11 countries, using daily data from December 14, 2007 to March 8, 2013.[6]

Our major findings are twofold. First, our results suggest that contagion from the European sovereign debt crisis to banks' equity returns has been confined to European banks, as U.S. banks' equity returns did not significantly react to the crisis. Second, across banks from the eurozone, we show that German financial institutions have been relatively less affected by the sovereign debt crisis. Indeed, for Germany nonlinearities are observed only for very high values of the transition variable that appear exclusively in the immediate aftermath of Lehman Brothers' collapse.

The rest of this paper is organized as follows. Section 2 presents the main related literature. Section 3 introduces the model and the data used in the smooth transition regressions (STR). Section 4 analyzes the results and section 5 concludes.

## 2. Related Literature

Our paper is closely related to two strands of the existing literature. The first one investigates the determinants of equity returns and credit risks in the banking sector. The second strand analyzes the extent of contagion from the sovereign debt crisis to banks.

Alter and Schuler (2012) contribute to the first strand of the literature. They examine whether the sovereign default risk exerts an influence on the default risk of the banking sector in the euro area. To this end, they consider daily credit default swap (CDS) spreads from 7 eurozone member states and 21 banks over the period June 2007-May 2010. Their main aim is to determine to what extent these CDS spreads' interdependencies differ before (June 2007-mid-September 2008) and after (late-October 2008-May 2010) the implementation of bank bailout programs by European governments and institutions. In order to analyze the dynamics of the short- and long-run interdependencies, Alter and Schuler (2012) estimate bivariate vector error correction and bivariate vector autoregressive models.[7] They find that, while before the bailouts the sovereign CDS spreads affect only marginally the bank CDS spreads from the same country, their influence tends to become permanent in the period following the implementation of the bailout programs. Gross and Koky (2013) also explore the interdependencies across sovereign CDS spreads and bank CDS spreads but through a Global vector autoregressive (GVAR) model.[8] Their sample comprises 23 sovereigns and 41 banks from Europe, the United States, and Japan. It covers daily data from January 2008 to April 2013. Their results suggest that sovereign-to-bank spillovers have been particularly intense in 2011-2012 when the euro area sovereign debt crisis was at its peak. Using panel estimations with cross-section fixed effects Arnold (2012) examines spillover of sovereign risk to the banking sector. He introduces interactions effects that measure the level of exposure to GIPS - based on

[6] Table A1 in Appendix gives the list of countries and banks studied in this paper.
[7] Each VEC (VAR) model includes a sovereign CDS spread and a selected domestic bank CDS spread.
[8] Unlike usual GVAR, the model considers two cross-sections (individual banks and sovereigns). Gross and Koky (2013) introduce a new methodology allowing endogenous interactions between cross-sections: the Mixed Cross-Section (MSC-GVAR).

July 2010 stress tests - and whether the bank originates from GIPS (Greece, Ireland, Portugal, and Spain). Arnold (2012) estimates co-variations between combined GIPS Sovereign CDS spreads and banking risks during time windows centered on the weekend of May 8-9, 2010.[9] Banking risks are measured with banks' stock returns and CDS rates.[10] Two results are especially interesting. First, an increase in the combined Sovereign CDS rates in GIPS exerts a negative influence on the banking sector risk (i.e. banks' CDS spread increase and banks' stock returns fall). Second, banks heavily exposed to GIPS seem stronger impacted by the increase in sovereign CDS spread, but this result is mainly driven by banks originated from the GIPS.

Whereas the previous studies are mainly based on CDS data and when they use data on banks stocks (Arnold, 2012) do not rely on an explicit model of stock returns, Poirson and Schmittman (2013) estimate a variant of the world Capital Asset Pricing Model (CAPM) with a country-specific factor. Their sample includes daily stock returns from December 2002 to November 2011 for 83 banks from 21 countries. In a first step the authors estimate every six months the banks' betas with respect to the global and country-specific factors. In a second step, Poirson and Schmittman (2013) investigate whether banks' fundamentals – including foreign exposure to GIIPS sovereign bonds, profitability and credit quality – explain the differences in banks' betas. Results suggest that the sensitivity of banks to global factors (beta of the global factor) increases in times of strong market volatility: in 2008-2009 in the aftermath of Lehman Brothers collapse and in 2011 with the European debt crisis. Interestingly, Poirson and Schmittman (2013) confirm the findings by Chan-Lau et al. (2012) concerning the regional dimension of the European debt crisis: the European debt crisis affects more European banks (including the United Kingdom) than banks located in other regions. Contrary to Poirson and Schmittman (2013) Chan-Lau et al. (2012) do not rely explicitly on the CAPM, but investigate empirically the impact of various measures of financial and economic conditions on monthly equity returns for a sample of 68 banks headquartered in 11 advanced countries over the period January 2006-October 2011. Results from their fixed-effect panel regressions show that sovereign risk – approximated by the arithmetic average of the CDS spreads of GIIPS plus Belgium - increasingly explains equity returns in the banking sector after 2008. In addition, Chan-Lau et al. (2012) stress that bank-specific characteristics matter, as higher capitalization, lower leverage, and less reliance on wholesale funding improve the resilience of banks (equity returns).

The second strand of the relevant literature investigates more directly contagion effects from sovereign debt crises to the banking sector.

De Bruyckere et al. (2013) define contagion as "excess correlation", that is to say a correlation over and above that resulting from economic fundamentals. Starting from this definition, their main aim is twofold. On the one hand, they estimate a factor model to identify the presence of contagion effects between banks and countries of the eurozone. On the other hand, they investigate whether bank- and country-

[9] Two time windows are considered: one month and two months. On 8-9 May, 2010, European Union members agreed to implement a rescue funds for governments experiencing refinancing problems in bond markets.

[10] The sample includes 51 banks drawn from the 91 banks that participated in the July 2010 stress tests for which CDS rates and stock prices are available.

specific characteristics drive the excess correlation. Their study covers 15 countries and 40 banks over the period 2007-2012. Changes in banks and sovereign CDS spreads are controlled by a set of variables encompassing market-wide credit risk, market-wide business climate changes in the European Union, investors fear indicator, and market expectations about future conditions in the financial markets. De Bruyckere et al. (2013) get three major findings. First, they identify significant evidence of contagion between banks and sovereigns CDS spreads during the European debt crisis. Second, as banks' government exposures exhibit home bias, they show that contagion effects are stronger between banks and their home country. Third, as in previous studies, the intensity of contagion is influenced by bank-specific characteristics. For instance, bank capital adequacy and the extent of reliance on short-term sources influence the degree of contagion. Preferring the framework of a vector autoregressive model Alter and Beyer (2014) quantify the sovereign-banks feedback loop using daily sovereign and bank CDS spreads from 11 eurozone countries and 34 banks over the period October 2009-July 2012. More specifically, the authors estimate a vector autoregressive model with exogenous variables (VARX). These exogenous variables allow taking into account common factors that influence at the same time all sovereign and banks CDS spreads. In a second step, Alter and Beyer (2014) aggregate results from the VARX models into a "Contagion Index". This index can be decomposed into four components: (i) amongst sovereigns, (ii) amongst banks; (iii) from sovereigns to banks, and (iv) from banks to sovereigns. The authors find an upward trend concerning both the contagion index of sovereigns and the overall contagion index. In periods of stress, the feedback loop intensifies. Finally, shocks on Spanish sovereign CDS spread suggest that "non-core" countries (Greece, Ireland, Italy, and Portugal) are more sensitive than "core" countries (Austria, Belgium, Finland, France, Germany, and the Netherlands), but the difference between these groups decreases during times of distress.

Contrary to the two above mentioned papers Grammatikos and Vermeulen (2012) base their study of the contagion from sovereigns to the banking sector on banks' equity returns. More specifically they examine the sensitivity of daily stock returns of financial firms and non-financial corporations in 11 eurozone members to the U.S. stock returns, the euro-dollar exchange rate and the gap between Greek and German CDS spreads. In order to detect contagion they use dummy variables to test whether there is a shift in some of the coefficients during crises.[11] On the one hand, the authors find the presence of shift contagion as the transmission of shocks is stronger during the 2007-2010 crisis. On the other hand, after the collapse of Lehman Brothers stock returns of financial firms have been more sensitive to changes in the Greek-German sovereign CDS spread. This suggests a contagion from sovereigns to banks. In a similar vein, Bhanot et al. (2014) investigate the impact of changes in Greek bond yield spreads on the daily abnormal financial sector returns in euro area crisis countries (Portugal, Italy, Greece, and Spain) and in non-crisis countries (Austria, Belgium, France, and the Netherlands) from January 2005 to June 2011. They assess whether changes in the Sovereign Greek bond yield exhibit stronger impact in crisis periods or in the aftermath of news announcements. Like Grammatikos and Vermeulen (2012) they rely on a crisis dummy.

[11] To determine the starting point of the financial crisis, Grammatikos and Vermeulen (2012) follow the Federal Reserve Bank of St. Louis' crisis timeline.

Bhanot et al. (2014) also explore for evidence of news spillovers. To this end, they collect news announcements for Greece and the rest of the eurozone and construct good and bad news dummies. Bhanot et al. (2014) find evidence of spillovers from the Greek bond yield to eurozone financial stock returns on days when there are ratings downgrades, suggesting the presence of information effects. In addition, they show that non-crisis countries are affected by ratings downgrades and bad news concerning Greece from the European Commission and the International Monetary Fund.

Overall the results of the related literature point at some nonlinear transmission of shocks to banks during the period 2007-2011 and, more specifically, at some spillovers from the GIPS Sovereign debt crisis to the banking sector. We contribute to this literature in two ways. First, by using a variant of the Fama-French-Carhart multifactor model of banks' stock returns to control more comprehensively for the different channels of risk transmission to banks' stocks. Second, through a nonlinear modelling, allowing for an endogeneous definition of crisis periods and for a smooth transition between regimes. The model and the methodology used are presented in detail in the next section.

## 3. Methodology and Data

### The Model

To assess whether and how the stock returns of European and U.S. banks have been impacted by the sovereign European debt crisis and by the previous episodes of financial turmoil experienced since 2007 we start from the four-factor model of Carhart (1997):

$$R_{p,t} = \alpha + \beta_M R_{M,t} + \beta_{SMB} R_{SMB,t} + \beta_{HML} R_{HML,t} + \beta_{MOM} R_{MOM,t} + \varepsilon_{p,t} \qquad (1)$$

Where $R_{p,t}$ is the excess return of banks stocks over the risk free interest rate, $R_{M,t}$ is the excess global stock market return over the risk free interest rate, $R_{SMB,t}$ is the spread between the returns on small and big stocks, $R_{HML,t}$ is the spread between the returns of high book-to-market stocks (value stocks) and low ones (growth stocks), $R_{MOM,t}$ is the spread between the returns of past winners (stocks with the highest prior returns) and past losers (stocks with the lowest prior returns).

Equation (1) nests the three-factor model of Fama and French (1993) as the special case where the momentum factor drops out ($\beta_{MOM}$=0). Fama and French (1996) advocate that their three-factor model is the best benchmark model, as it accounts for most of the market anomalies left unexplained by the one factor Sharpe (1964) - Lintner (1965) CAPM. Indeed, following Fama and French (1993) the empirical success of their model allows its interpretation as an equilibrium multifactor model of stock returns, consistent with the arbitrage pricing theory of Ross (1976). In this framework, $R_{M,t}$, $R_{SMB,t}$ and $R_{HML,t}$ can be interpreted as three common sources of risk across stocks, namely the market risk of the CAPM $(R_{M,t})$ and two other non-diversifiable risks: a small size risk, captured by $R_{SMB,t}$, and a distress risk, captured by $R_{HML,t}$. However Fama and French (1996) acknowledge that their three-factor model does not account for the short run persistence of returns or momentum effect put into evidence by Jegadeesh and Titman (1993). Therefore, following Carhart (1997) we use the more general four-factor model.

The sovereign European debt crisis of 2010-2011 has undermined the recovery of European banks from the financial and banking crisis of 2007-2008: the downgrading of sovereign ratings has fuelled the downgrading of banks, the sovereign debt holdings of banks have depreciated as has the implicit sovereign guarantee to banks. The consequences of sovereign risks for the private sector of advanced countries have long been deemed negligible and, as such, have been neglected by the mainstream financial literature on stocks common risk factors. To allow for the specific additional risk entailed by the European sovereign debt crisis we add to equation (1) a European sovereign risk factor $R_{SOV,t}$, proxied by the change in the sovereign CDS:

$$R_{p,t} = \alpha + \beta_M R_{M,t} + \beta_{SMB} R_{SMB,t} + \beta_{HML} R_{HML,t} + \beta_{MOM} R_{MOM,t} + \beta_{SOV} R_{SOV,t} + \varepsilon_{p,t} \qquad (2)$$

As shown in section 2, the previous results of the literature suggest that some nonlinearities may have played a part in the transmission of risks to banks' stocks, during the recent episodes of crises. In order to formally allow for nonlinearities in the model and test for shift contagion (Forbes and Rigobon, 2001), we turn to a STR extension of equation (2) in which the coefficients may change during crisis episodes:

$$\begin{aligned} R_{p,t} = {} & \alpha^L + \beta_M^L R_{M,t} + \beta_{SMB}^L R_{SMB,t} + \beta_{HML}^L R_{HML,t} + \beta_{MOM}^L R_{MOM,t} + \beta_{SOV}^L R_{SOV,t} \\ & + g(v_{t-\tau};\gamma,c)\left[\alpha^{NL} + \beta_M^{NL} R_{M,t} + \beta_{SMB}^{NL} R_{SMB,t} + \beta_{HML}^{NL} R_{HML,t} + \beta_{MOM}^{NL} R_{MOM,t} + \beta_{SOV}^{NL} R_{SOV,t}\right] + \varepsilon_{p,t} \end{aligned} \qquad (3)$$

Where the transition function $g(v_{t-\tau};\gamma,c)$ varies between 0 and 1 as the transition variable $v_{t-\tau}$ crosses the threshold *c*.

As we look for a transition variable $v_{t-\tau}$ that may represent crisis episodes in the eurozone we opt for the VSTOXX, the implied volatility of the Eurostoxx50, a eurozone stock market index. In the high volatility regime, when the VSTOXX is above its threshold value *c*, we expect that some shifts may affect the coefficients and that they will be captured through the estimated coefficients in the second (nonlinear) part of equation (3).

The usual transition function *g* takes a logistic or an exponential shape (Teräsvirta and Anderson, 1992). In the logistic STR with one threshold *c* (LSTR), the S shaped transition function rises from 0 to 1 with the VSTOXX ($v_{t-\tau}$). It is defined as:

$$g(v_{t-\tau};\gamma,c) = \frac{1}{1+e^{-\gamma(v_t-c)}} \quad \text{with } \gamma>0$$

Following Jansen and Teräsvirta (1996), the extension from one to two thresholds $c_1$ and $c_2$ gives rise to a U shaped transition function and to the exponential STR (ESTR) model. The transition function then becomes:

$$g(v_{t-\tau};\gamma,c)=\frac{1}{1+e^{-\gamma(v_t-c_1)(v_t-c_2)}}$$ with $\gamma>0$ and $c_2 > c_1$

In both transition functions a low slope parameter $\gamma$ results in a smooth transition. In the extreme case where $\gamma = 0$, $g$ is constant and the STR reduces to a linear equation. In the opposite case where $\gamma$ takes very high values the transition function g jumps from 0 to 1, according to the value of the threshold(s). In the LSTR model it jumps from 0 to 1 when $v_{t-\tau}$ rises above $c$. In the ESTAR model it jumps from 0 to 1 in two cases: when $v_{t-\tau}$ rises above $c_2$ and when it decreases below $c_1$.

In our framework we expect the transition function $g$ to increase only when the VSTOXX rises above a relatively high threshold but not when the VSTOXX decreases below a more moderate threshold. Therefore a LSTR shape seems more appropriate than an ESTAR one. However, we follow the test sequence advocated by Teräsvirta (1994) to test for nonlinearities and choose the appropriate shape for $g$.

Testing for nonlinearities in equation (3) is nonstandard because of nuisance parameters (Hansen, 1996) that are not identified under the null hypothesis. We therefore resort to the auxiliary regression proposed by Luukkonen et al. (1988):

$$R_{p,t} = \theta'_0\, x_t + \theta'_1\, x_t v_{t-\tau} + \theta'_2\, x_t v_{t-\tau}^2 + \theta'_3\, x_t v_{t-\tau}^3 + \xi_t \qquad (4)$$

Where $x_t$ is a vector containing the constant and the explanatory variables of equation (2)

Testing for linearity amounts to test:

$H_0$: $\theta'_1 = \theta'_2 = \theta'_3 = 0$

If linearity is rejected, following Teräsvirta (1994) we proceed to three exclusion tests:

$H_{04}$: $\theta'_3 = 0$

$H_{03}$: $\theta'_2 = 0 \mid \theta'_3 = 0$

$H_{02}$: $\theta'_1 = 0 \mid \theta'_2 = \theta'_3 = 0$

The rejection of $H_{03}$ supports the choice of an ESTR model, while the rejection of $H_{04}$ and/or of $H_{02}$ leads to an LSTR model.

## Data

Our data span the period 14/12/2007-08/03/2013 that encompasses (Figure A2) four episodes of crises, namely: the subprime crisis of 2007/2008, followed by the global crisis after the failure of Lehman Brothers, then in 2010 the Greek crisis, followed by the eurozone crisis[12]. High levels of stock market volatility – captured through a VSTOXX above thresholds of 30 and 40 – characterize these crises. Though dependent, these four episodes present some differences: the period following the collapse of Lehman Brothers is clearly characterized by a record volatility, much higher than the levels observed during the three other crisis episodes. The two last crises are not only characterized by a more subdued

[12] 14/12/2007 is the earliest date at which the Sovereign CDS series were available for European countries on Datastream.

volatility, they are also much more local crises, mainly focused on European countries. To better capture these two last crises we choose the VSTOXX (with 1 to 5 lag(s)), extracted from Macrobond, as the transition variable of our nonlinear STR model. The VSTOXX is very close to the VIX, the implied volatility of the U.S. S&P500 stock market index. Like the VIX it captures well the periods of global financial turmoil and high risk aversion and it can also be interpreted as an indicator of the global financial cycle (Rey, 2013). However, the VSTOXX being based on the eurozone STOXX stock market index, it is by construction better suited than the VIX to capture the financial turmoil in Europe, during the Greek and eurozone crises. Indeed the VSTOXX remains above the VIX during these periods, while it is nearly identical to the VIX during the Subprime and the Global crises.

We study the daily returns on banks stocks from ten European countries –Belgium (BE), Germany (DE), Spain (ES), France (FR), the U.K. (GB), Greece (GR), Ireland (IE), Italy (IT), the Netherlands (NE), Portugal (PT)- and for purposes of comparison, we extend our analysis to U.S. banks. The series $R_{p,t}$ of banks' stock excess returns is computed for each country from an average of the total daily stock returns of the banks of the country minus the 3 months government interest rate. The list of banks per country is detailed in the Appendix. We consider banks for which both quotation and CDS are available, as their stocks are the most liquid ones and to facilitate comparisons with the related literature. The stock returns are extracted from Datastream. The 3 months government interest rates are the 3 months yields of government benchmarks from Macrobond.

The global market factor $R_{M,t}$ is calculated as the difference between the daily total return of the MSCI, IMI Equity Index extracted from Macrobond and the 3 months U.S. government yield benchmark. The size $R_{SMB,t}$ and book-to-market $R_{HML,t}$ variables are the Fama and French research factors, uploaded from the website of Kenneth French, where their exact description can be found.[13] The momentum factor $R_{MOM,t}$ comes from the same source.[14] These three risk factors are available on a daily basis only for the US: therefore they reflect the size, book-to-market and momentum effects measured on the U.S. stock market. Any positive (negative) correlation of European banks stock returns with these factors may therefore also represent a positive (negative) correlation with the U.S. stock market. All these explanatory variables are converted to the local currency of the banks' country: either the EUR, or the GBP or the USD.

To construct the proxy $R_{SOV,t}$ of sovereign debt risk in the eurozone we use 5 years eurozone Sovereign senior CDS indices extracted from Datastream. As is apparent from Figure A3 the countries that experienced the highest increases of their Sovereign CDS indices during the European crisis are Greece, Ireland and Portugal (GIP). We therefore calculate an average sovereign CDS index for the GIP countries, using as weights the relative percentages of their governments consolidated gross debts extracted from

[13] See http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/Data_Library/f-f_factors.html.
[14] See http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/Data_Library/det_mom_factor_daily.html.

Eurostat over 2007-2012. We then calculate $R_{SOV,t}$ simply as the first difference of the logged GIP CDS index.

## 4. Results

As a first step, following the recommendation of Terasvirta (1994) and to provide a benchmark, we estimate the linear version of the model (Eq. 2) for each of the eleven countries under study. We then proceed to the estimation of the LSTR model of Equation (3).

### Results for the linear regressions of banks' returns

The estimations of the linear equation of returns (Eq. 2), reported in table A2 confirm that our extended version of the Carhart four factors model is appropriate to capture the main common factors of risks of banks' stocks. To account for the conditional heteroskedasticity detected by the LM-ARCH test of Engle (1982) we estimate jointly the extended version of the Fama-French-Carhart model (Eq. 2) for the returns and a GARCH(1,1) model for the conditional volatility. Besides we account for the slight autocorrelation that may characterize stock returns by adding up to five lags of the dependent variable as explanatory variables in the return equation[15].

According to results of the estimations of equation (2) reported in table A2 the equity returns of banks commove strongly with the global market factor, with estimates for the global market beta $(\beta_M)$ above or equal to one, except for Germany and Portugal. This result is quite consistent with the conclusions of Poirson and Schmittman (2013), who remark that over the period 2007-2011 banks' stocks are characterized by high global market betas. It contrasts with the negative estimates that we find for the betas of the other three Fama-French-Carhart factors for the European countries. European banks' equity returns appear indeed to be positively correlated with the returns of big rather than small U.S. firms $(\beta_{SMB} < 0)$, low book-to-market U.S. stocks rather than high ones $(\beta_{HML} < 0)$ and past losers rather than past winners $(\beta_{MOM} < 0)$. This last feature is shared by U.S. banks whose momentum beta appears unsurprisingly to be also negative: the banking sector was globally one of the most adversely hit by the financial turmoil over the period 2007-2013, hence its positive correlation with stocks characterized by bad performances. The similarity between U.S. and European banks' returns ends there: contrary to European banks U.S. banks are characterized by a zero SMB beta and a positive HML beta, causing some decoupling of U.S. and European banks' returns. This partial disconnection has been further strengthened by the euro area sovereign debt crisis: whereas European banks stocks are adversely hit by the rise in the

[15] As these lags do not in general appear to be significant and are not the core of our model, we do not report their estimated coefficients. To add or remove these lags does not change the coefficients of the other 5 explanatory variables of equation (2). But we prefer to keep them in the regression as slight autocorrelations over the past week (five days) may be statistically difficult to detect.

sovereign CDS of the GIP – with estimates for $\beta_{SOV}$ ranging from -0.26 for Greece to -0.05 for Germany and the UK – the U.S. are spared from any direct negative impact. U.S. banks' equity returns even appear to slightly benefit from the eurozone crisis $(\widehat{\beta}_{SOV} = 0.02)$, a result that suggests that some flight-to-quality may be at work.

Nonlinearities in the final estimations

The results of the nonlinearity tests and of the choice between LSTR and ESTR models are reported in Table A3. Linearity is consistently rejected and the selected model is always an LSTR.

The final results of the Smooth Transition Regressions based on the multifactor stock return model of equation 3 are displayed in Table A4 and commented in detail below and in the following paragraphs. Misspecifications tests are reported in table A5 in appendix.

The nonlinear LSTR1 model with the VSTOXX ($\nu_{t-\tau}$) as a transition variable is supported by the results of the smooth transition regressions. With the notable exception of Greek banks returns, whose constant becomes – unsurprisingly - negative in periods of high volatility ($\alpha^{NL}$ = -1.13), the constant does not change across regimes and is generally not significant in any regime. But – with the exception of the U.K. - all countries experience significant shifts in the factors coefficients when the European Stock market volatility increases: some shift contagion seems to have been at work during the last crises. Besides, as is apparent from Figures A4 to A14 displayed in appendix, the estimated transition parameters $c$ and $\gamma$ yield the typical S shaped $g(\nu_{t\tau}; \gamma, c)$ transition functions characteristic of smooth transitions between regimes. The smoothest transitions (low slope parameter $\gamma$) are observed for French banks, while German banks' returns experience the roughest transitions. However, according to the threshold estimate found for Germany (second column and last line of Table A3) the rough transition towards the high volatility regime only affects Germany when the VSTOXX hits record highs equal or above a threshold $c$ of 60. As is apparent from Figure A2 it only happens for a short time in October and November 2008, in the aftermath of Lehman's bankruptcy filing.

The linear and nonlinear impact of the global market factor

According to the estimates of Table A4 for the global stock market beta in the low volatility regime, $\beta_M^L$ ranges from 0.91 for Germany to 2.19 for the Netherlands: over the period 14/12/2007-08/03/2013: when the VSTOXX stays well below its threshold $c$, banks returns are characterized by a high exposure to global market movements. This result is broadly consistent both with our previous results from the estimation of the linear equation (2) and with Poirson and Schmittman (2013) who find a global market beta of European banks above 1 during the period 2007-2011. However our STR model allows us to go one step further and to put into evidence strong nonlinearities in the dynamics of the European banks' global market beta. In periods of high European Stock Market volatility the correlation drops sharply between the European banks stock returns and the global market: $\beta_M^{NL}$ is sizeable and mostly significantly negative for European countries[16]. The sum $\beta_M^L + \beta_M^{NL}$ is even negative for France, turning the positive relationship between bank returns and the global market factor into a negative one when the transition function $g(\nu_{t-\tau}; \gamma, c)$ approaches 1. However the relatively low slope parameter $\gamma$ and high threshold c found for this country means that its transition function increases slowly with the VSTOXX ($\nu_{t-\tau}$) and takes mostly values well below 1. Anyway the large decoupling between banks stock returns and the global stock market in periods of high European Stock market volatility seems specific to Europe: the global market beta of U.S. banks does not change significantly with the VSTOXX. These results confirm that the recent crisis episodes have had some asymmetric effects on European and U.S. banks.

The linear and nonlinear impact of the size factor SMB

As the European banks of our sample are mostly relatively big companies, it is only natural that their stock returns be inversely correlated with the SMB factor. In the low volatility regime the negative values found for $\beta_{SMB}^L$ were therefore to be expected. They confirm the results obtained from the linear regression (Eq. 2). It is worth noting that the linear negative dependence on the SMB factor is less marked for German banks and that the U.S. banks returns display no significant linear or nonlinear dependence on the SMB factor. Besides, the SMB betas of European banks appear to be sensitive to VSTOXX changes. In the high volatility regime the SMB betas of European banks increase sharply $(\beta_{SMB}^{NL} > 0)$ and significantly in six cases out of ten and for Germany, France and Ireland they even turn positive $(\beta_{SMB}^L + \beta_{SMB}^{NL} > 0)$ when the VSTOXX hits record highs. However the partial recoupling between European banks stocks and the SMB factor in the high volatility regime is not really good news for the European banking sector: even if the small firm versus big firm premium is positive on average over the whole period it decreases and becomes slightly negative when the VSTOXX is above 40.

The linear and nonlinear impact of the book-to-market factor HML

In the linear part of the model the evidence concerning the book-to-market impact on banks stock returns is relatively clear-cut and consistent with the results of the linear regression (Eq. 2) previously reported. In ten cases out of eleven the book-to-market factor is significant at the 1% level, with a notable difference between European banks, for which $\beta_{HML}^L$ is negative, and the U.S. banks, for which it is positive. In other terms European banks appear to be correlated with low book-to-market U.S. stocks and U.S. banks with high book-to-market ones. This difference between European and U.S. banks might be explained by the delay with which, compared to U.S. banks, European banks have been recapitalized and have cleaned up their distressed assets from their balance sheets after the 2007-2008 crisis. Due to the European Sovereign debt crisis in 2010-2012 European banks also have to cope with a higher proportion of distressed Sovereign assets than U.S. banks. Contrary to the global market factor and the size factor, the

[16] The conservative estimates of the standard errors – corrected for heteroskedasticity and autocorrelation – increase the marginal significance levels above 10% for Germany, the U.K. and the Netherlands.

book-to-market factor does not have much significant nonlinear impact on banks stock returns. The only exceptions concern the German and the U.S. banks for which the initial linear impact – negative for Germany, positive for the U.S. – is further enhanced in the high VSTOXX regime: a high VSTOXX disconnects further the dynamics of the German banks from the one of U.S. banks.

The linear and nonlinear impact of the momentum factor

As could be expected over 2007-2013, banks' stocks – whether from Europe or from the United States - display a negative dependence on the momentum factor. In other terms their returns display a positive correlation with those of past losers. As the momentum factor relies on the short term persistence of past performances this result reflects the fact that banks stocks have globally badly performed over 14/12/2007-08/03/2013. It is again consistent with the results obtained from the linear regression (Eq. 2). The momentum factor does not appear to be subject to much nonlinearities, the only exception at a 10% significance level being Portugal, with a positive estimate for $\beta_{MOM}^{NL}$ (while $\beta_{MOM}^{L} + \beta_{MOM}^{NL}$ stays negative).

The linear and nonlinear impact of GIP Sovereign CDSs

The results displayed in Table A3 confirm that in all the European countries under study banks' returns have at some point been negatively impacted by the rise in the Sovereign CDS of Greece, Ireland and Portugal (GIP). Indeed, either $\beta_{SOV}^{L}$ and/or $\beta_{SOV}^{NL}$ are negative and their sum is always below zero: when the VSTOXX surges above a threshold (*c*) estimated between 30 (for Spain) and 63 (for the UK) European banks stock returns drop in response to a rise in the Sovereign risk of the three countries most adversely hit by the European sovereign debt crisis. This finding is broadly consistent with the results of Chan-Lau et al. (2012) and Grammatikos and Vermeulen (2012) concerning the transmission of Sovereign risks to banks during the period 2008-2011. For Germany this negative impact is slight ($\beta_{SOV}^{L}$=-0.04 and $\beta_{SOV}^{NL}$=0 cannot be rejected), but nonetheless significant. For some countries, such as Greece, the negative linear impact is more sizable ($\left|\beta_{SOV}^{L}\right|$ being larger) - which may explain why Arnold (2012) mainly captures this effect - though it does not appear to be further strengthened when the VSTOXX increases sharply[17]. But for many European countries the nonlinear effect is dramatic: it is mostly when the VSTOXX rises above its threshold *c* that the high risk aversion and the European economic downturn cause banks stock returns to plummet in reaction to a hike in GIP sovereign CDSs. Not surprisingly the Irish banks are amongst the most severely affected, a result again consistent with Arnold (2012). But, in line with the conclusions of Bhanot et al. (2014) and Grammatikos and Vermeulen (2012), we find that some shift contagion appears to spread the negative impact of the GIP Sovereign risks outside the GIP and, in

[17] At a 10% significance level $\beta_{SOV}$ appears even to increase for Greece and Spain $(\beta_{SOV}^{NL} > 0)$ during periods of high volatility, though the sum $\beta_{SOV}^{L} + \beta_{SOV}^{NL}$ stays negative

particular, it harshly hits the Belgian, Italian and French banks for which the estimates of $\beta_{SOV}^{NL}$ are largely negative. These results contrast with the one found for U.S. banks, which seem to stay mostly unharmed by the direct impact of the European Sovereign debt crisis. At a 10% significance level U.S. banks returns appear even to slightly benefit ($\beta_{SOV}^{L}>0$) from the European turmoil through a kind of flight to quality effect, a result that confirms our previous estimate from Eq. 2

## 5. Conclusion

This paper provides some empirical evidence on contagion and on the impact of the eurozone sovereign debt crisis on European and U.S. banks' stock returns during the successive episodes of crises of the period 2007-2013. More specifically, we use an explicit multifactor model for banks' equity returns and extend it to a nonlinear context to test for shift contagion and to assess to what extent the European sovereign debt crisis has exerted an influence on banks' equity returns. The use of a variant of the Carhart-Fama-French model allows us to control for the multiple common risk factors other than sovereign risk that may have impacted banks' stock returns over the period. Besides, we capture changes in parameters associated with shift contagion by estimating a STR extension of this multifactor model. The main advantages of this nonlinear approach are to allow for an endogenous definition of crisis periods and for smooth transitions between regimes. Our findings suggest that contagion effects have been mostly limited to euro area banks and that the delay in the cleaning up of their balance sheets of distressed assets has probably put them at a disadvantage relatively to their U.S. counterparts. In addition, if we focus more particularly on the impact of GIP (Greece, Ireland, and Portugal) sovereign CDS, we show that none of the European banks stock returns have been spared by the European sovereign debt crisis and that shift contagion effects appear beyond the banks located in GIP countries and concern also Belgium, France and Italy. This result contrasts with the one found for U.S. banks, which seem to be unharmed by the direct impact of the European Sovereign debt crisis and even to slightly benefit from the European turmoil through a kind of flight-to-quality effect.

In terms of policy implications, our results clearly suggest that a resolution of the sovereign debt crisis is a prerequisite to strengthen the stability of the European banking system. From this standpoint, there is a complementarity between the European banking union project and the implementation of mechanisms allowing the resolution of the sovereign debt crisis at the European level. More particularly, our findings echo the studies stressing the structural changes about the public debt management implied by the creation of the monetary union.[18]

[18] See, for instance, Pisani-Ferry (2012), De Grauwe and Ji (2013) and Krugman (2013).

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Appendix

**Table A1**: List of countries and banks

| | |
|---|---|
| **Belgium** | KBC Bank |
| **France** | BNP Paribas, Crédit Agricole S.A., Natixis, Société Générale |
| **Germany** | Commerzbank, Deutsche Bank, IKB Deutsche Industriebank, Landesbank Berlin Holding, Landesbank Hessen-Thuringen Giro Genussscheine |
| **Greece** | Alpha Bank, Eurobank Ergasias S.A., National Bank of Greece |
| **Ireland** | Allied Irish Banks, Bank of Ireland, Permanent TSB Group Holdings |
| **Italy** | Banca Monte Dei Paschi, Intesa Sanpaolo, Mediobanca, Unicredit |
| **Netherlands** | Aegon, ING |
| **Portugal** | Banco Comercial Portugues, Banco Espirito Santo |
| **Spain** | Banco De Sabadell, Banco Popular Espanol, Banco Santander, Banco Bilbao Vizcaya Argentaria, Banco Intercontinental Espanol |
| **United Kingdom** | Barclays, HSBC, Lloyds Banking Group, Royal Bank of Scotland, Standard Chartered |
| **United States** | American Express, Bank of America, Bank of New York Mellon, Capital One Financial, Citigroup, Goldman Sachs, Morgan Stanley, PNC Financial Services |

**Table A2**: Results of the linear estimations of the multifactor model of bank returns

| | *BE* | *DE* | *ES* | *FR* | *GB* | *GR* | *IE* | *IT* | *NE* | *PT* | *US* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\alpha$ | 0.11 (0.13) | -0.02 (0.59) | -0.02 (0.62) | 0.03 (0.61) | -0.01 (0.86) | -0.04 (0.73) | -0.27 (0.02) | -0.03 (0.48) | 0.04 (0.52) | -0.04 (0.46) | -0.03 (0.35) |
| $\beta_M$ | 1.71 (<0.01) | 0.83 (<0.01) | 1.10 (<0.01) | 1.84 (<0.01) | 1.66 (<0.01) | 1.00 (<0.01) | 1.50 (<0.01) | 1.21 (<0.01) | 1.97 (<0.01) | 0.60 (<0.01) | 1.47 (<0.01) |
| $\beta_{SMB}$ | -0.85 (<0.01) | -0.15 (<0.01) | -0.51 (<0.01) | -0.89 (<0.01) | -0.71 (<0.01) | -0.56 (<0.01) | -0.74 (<0.01) | -0.49 (<0.01) | -0.74 (<0.01) | -0.40 (<0.01) | 0.02 (0.72) |
| $\beta_{HML}$ | -0.38 (<0.01) | -0.27 (<0.01) | -0.44 (<0.01) | -0.67 (<0.01) | -0.36 (<0.01) | -0.48 (<0.01) | -0.24 (<0.01) | -0.52 (<0.01) | -0.72 (<0.01) | -0.19 (0.01) | 1.32 (<0.01) |
| $\beta_{MOM}$ | -0.56 (<0.01) | -0.38 (<0.01) | -0.35 (<0.01) | -0.53 (<0.01) | -0.52 (<0.01) | -0.23 (<0.01) | -0.59 (<0.01) | -0.39 (<0.01) | -0.65 (<0.01) | -0.18 (<0.01) | -0.56 (<0.01) |
| $\beta_{SOV}$ | -0.15 (<0.01) | -0.05 (<0.01) | -0.08 (<0.01) | -0.10 (<0.01) | -0.05 (<0.01) | -0.26 (<0.01) | -0.09 (<0.01) | -0.10 (<0.01) | -0.09 (<0.01) | -0.13 (<0.01) | 0.02 (<0.01) |
| $c$ | 0.10 (0.05) | 0.14 (<0.01) | 0.06 (<0.01) | 0.06 (0.01) | 0.04 (0.04) | 0.22 (0.04) | 1.19 (<0.01) | 0.04 (<0.01) | 0.04 (0.12) | 0.10 (0.02) | 0.03 (<0.01) |
| $a$ | 0.11 (<0.01) | 0.17 (<0.01) | 0.08 (<0.01) | 0.09 (<0.01) | 0.08 (<0.01) | 0.09 (<0.01) | 0.18 (<0.01) | 0.09 (<0.01) | 0.10 (<0.01) | 0.10 (<0.01) | 0.13 (<0.01) |
| $b$ | 0.89 (<0.01) | 0.77 (<0.01) | 0.90 (<0.01) | 0.90 (<0.01) | 0.91 (<0.01) | 0.90 (<0.01) | 0.78 (<0.01) | 0.90 (<0.01) | 0.90 (<0.01) | 0.89 (<0.01) | 0.86 (<0.01) |
| ARCH | 291.74 (<0.01) | 166.66 (<0.01) | 45.81 (<0.01) | 140.24 (<0.01)) | 185.69 (<0.01)) | 117.49 (<0.01)) | 150.14 (<0.01)) | 74.64 (<0.01) | 31.63 (<0.01) | 91.34 (<0.01) | 276.39 (<0.01) |
| AR | 2.90 (0.82) | 3.39 (0.76) | 5.96 (0.43) | 1.07 (0.98) | 7.12 (0.31) | 4.63 (0.59) | 2.42 (0.88) | 3.25 (0.78) | 7.91 (0.24) | 4.70 (0.58) | 9.62 (0.14) |

Note: This table reports the results from the estimation of Eq. (2) over 14/12/2007-08/03/2013:

$$R_{p,t} = \alpha + \beta_M R_{M,t} + \beta_{SMB} R_{SMB,t} + \beta_{HML} R_{HML,t} + \beta_{MOM} R_{MOM,t} + \beta_{SOV} R_{SOV,t} + \varepsilon_{p,t}$$

together with the GARCH(1,1) model for the conditional variance $(h_t)$: $h_t = c + a\,\varepsilon_{t-1}^2 + b\,h_{t-1}$

Where $\beta_M$ and $\beta_{SMB}$, $\beta_{HML}$, $\beta_{MOM}$ denote the coefficients on, respectively, the market factor and on the three Fama-French and Carhart factors: small minus big firms returns, returns of high book to market firms minus low ones and a momentum factor. $\beta_{SOV}$ is the coefficient on the average change in the Sovereign CDS of Greece, Ireland and Portugal. Marginal significance levels are given in parentheses. The line ARCH reports the results of the LM-ARCH test of Engle (1982) of order 6 on non standardized residuals. The line AR reports the results for the Ljung-Box test for autocorrelation of order 6 non standardized residuals. Country codes are given in the data paragraph of Section 3.

**Table A3**: Testing for nonlinearity

| | τ | $H_0$ | $H_{04}$ | $H_{03}$ | $H_{02}$ | Selected model |
|---|---|---|---|---|---|---|
| *BE* | 2 | 3.7182e-12 | 5.7125e-07 | 1.8581e-01 | 4.6589e-08 | LSTR |
| *DE* | 1 | 1.3565e-14 | 1.8495e-12 | 7.2620e-03 | 1.2330e-03 | LSTR |
| *ES* | 5 | 9.8563e-15 | 3.9133e-04 | 1.0526e-02 | 2.4898e-12 | LSTR |
| *FR* | 1 | 9.3873e-40 | 3.1122e-09 | 1.9004e-04 | 1.5168e-31 | LSTR |
| *GB* | 1 | 3.6602e-27 | 1.3130e-08 | 3.4576e-05 | 4.1574e-18 | LSTR |
| *GR* | 5 | 7.4182e-04 | 7.1472e-02 | 2.2930e-02 | 9.3526e-03 | LSTR |
| *IE* | 1 | 2.1169e-09 | 1.2724e-01 | 5.6694e-04 | 6.8519e-08 | LSTR |
| *IT* | 1 | 1.8116e-15 | 4.8399e-04 | 8.3900e-02 | 2.1630e-14 | LSTR |
| *NL* | 1 | 1.9666e-27 | 7.6628e-17 | 8.5760e-04 | 1.4933e-11 | LSTR |
| *PT* | 1 | 7.7493e-07 | 2.0960e-01 | 5.1334e-02 | 1.9955e-07 | LSTR |
| *US* | 1 | 5.9710e-57 | 1.9436e-12 | 1.4743e-05 | 2.3329e-44 | LSTR |

*Note*: This table displays the results of the nonlinearity tests based on Eq. (4):

$$R_{p,t} = \theta'_0 x_t + \theta'_1 x_t v_{t-\tau} + \theta'_2 x_t v_{t-\tau}^2 + \theta'_3 x_t v_{t-\tau}^3 + \xi_t$$

Where $x_t$ is a vector containing the constant and the explanatory variables of equation (2) and where the transition variable $v_{t-\tau}$ is the VSTOXX with $\tau$ lags. The chosen lag $\tau$ minimizes the p-value of the nonlinearity test (Teräsvirta, 1994).

Column $H_0$ gives for the selected lag the p-value of the F-test of nonlinearity:

$H_0$: $\theta'_1 = \theta'_2 = \theta'_3 = 0$

Columns $H_{04}$, $H_{03}$ and $H_{02}$ give the p-values of the F-tests of the following hypotheses:

$H_{04}$: $\theta'_3 = 0$

$H_{03}$: $\theta'_2 = 0 \mid \theta'_3 = 0$

$H_{02}$: $\theta'_1 = 0 \mid \theta'_2 = \theta'_3 = 0$

Following Teräsvirta (1994), if the test of $H_{03}$ yields the smallest p-value we select an ESTR model, if not we opt for a LSTR model.

**Table A4**: Results of the nonlinear estimations of the multifactor model of bank returns

| | *BE* | *DE* | *ES* | *FR* | *GB* | *GR* | *IE* | *IT* | *NE* | *PT* | *US* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Linear Parameters* | | | | | | | | | | | |
| $\alpha^L$ | 0.09 | -0.07 | -0.04 | 0.01 | -0.01 | 0.03 | -0.22 | -0.10 | 0.01 | -0.06 | -0.03 |
| | (0.32) | (0.06) | (0.45) | (0.94) | (0.90) | (0.86) | (0.13) | (0.30) | (0.88) | (0.42) | (0.34) |
| $\beta_M^L$ | 1.93 | 0.91 | 1.37 | 2.10 | 1.81 | 1.14 | 1.85 | 1.56 | 2.19 | 0.98 | 1.46 |
| | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) |
| $\beta_{SMB}^L$ | -0.85 | -0.26 | -0.72 | -1.05 | -0.88 | -0.86 | -1.55 | -0.74 | -0.87 | -0.67 | -0.12 |
| | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (0.12) |
| $\beta_{HML}^L$ | -0.58 | -0.33 | -0.40 | -0.75 | -0.42 | -0.61 | -0.09 | -0.73 | -0.85 | -0.35 | 1.13 |
| | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (0.73) | (<0.01) | (<0.01) | (<0.01) | (<0.01) |
| $\beta_{MOM}^L$ | -0.74 | -0.32 | -0.51 | -0.55 | -0.52 | -0.39 | -0.38 | -0.62 | -0.67 | -0.34 | -0.58 |
| | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (<0.01) | (0.02) | (<0.01) | (<0.01) | (<0.01) | (<0.01) |
| $\beta_{SOV}^L$ | -0.12 | -0.04 | -0.11 | -0.06 | -0.04 | -0.28 | -0.04 | -0.03 | -0.05 | -0.08 | 0.02 |
| | (<0.01) | (<0.01) | (<0.01) | (0.11) | (0.08) | (<0.01) | (0.38) | (0.46) | (0.04) | (<0.01) | (0.06) |
| *Nonlinear Parameters* | | | | | | | | | | | |
| $\alpha^{NL}$ | -0.27 | 0.22 | 0.13 | 0.28 | 1.16 | -1.14 | 0.12 | 0.26 | -0.12 | -0.19 | -0.20 |
| | (0.79) | (0.75) | (0.27) | (0.79) | (0.46) | (0.02) | (0.94) | (0.50) | (0.91) | (0.42) | (0.29) |
| $\beta_M^{NL}$ | -1.44 | -0.37 | -0.61 | -2.47 | -2.42 | -0.67 | -1.59 | -1.15 | -1.82 | -0.69 | -0.11 |
| | (0.03) | (0.25) | (<0.01) | (<0.01) | (0.14) | (0.01) | (0.02) | (0.02) | (0.14) | (<0.01) | (0.54) |
| $\beta_{SMB}^{NL}$ | 0.45 | 0.65 | 0.49 | 1.92 | 0.55 | 0.58 | 3.03 | 0.95 | 0.34 | 0.52 | -0.05 |
| | (0.54) | (0.07) | (<0.01) | (<0.06) | (0.49) | (0.19) | (<0.01) | (0.08) | (0.71) | (0.02) | (0.80) |
| $\beta_{HML}^{NL}$ | 0.47 | -0.92 | -0.15 | 0.19 | -0.03 | 0.31 | -0.45 | 0.27 | 0.46 | 0.04 | 1.46 |
| | (0.55) | (0.07) | (0.27) | (0.80) | (0.97) | (0.51) | (0.66) | (0.43) | (0.52) | (0.84) | (<0.01) |
| $\beta_{MOM}^{NL}$ | 0.42 | -0.29 | 0.10 | -0.16 | 0.24 | 0.06 | -0.71 | 0.20 | -0.32 | 0.26 | -0.08 |
| | (0.42) | (0.24) | (0.31) | (0.68) | (0.65) | (0.79) | (0.19) | (0.37) | (0.55) | (0.08) | (0.60) |
| $\beta_{SOV}^{NL}$ | -0.70 | -0.09 | 0.05 | -0.36 | -0.27 | 0.17 | -0.47 | -0.21 | -0.36 | -0.08 | 0.02 |
| | (<0.01) | (0.27) | (0.10) | (0.07) | (0.35) | (0.07) | (0.02) | (0.04) | (<0.20) | (0.17) | (0.36) |
| *Transition Parameters* | | | | | | | | | | | |
| $\gamma$ | 2.51 | 472 | 15.6 | 0.91 | 1.15 | 3.32 | 1.85 | 1.19 | 1.53 | 2.69 | 5.76 |
| $c$ | 48.9 | 59.6 | 30.9 | 56.9 | 63.2 | 41.7 | 51.8 | 43.4 | 55.8 | 41.5 | 40.6 |

Note: This table reports the results from the estimation of Eq. (3) over 14/12/2007-08/03/2013:

$$R_{p,t} = \alpha^L + \beta_M^L R_{M,t} + \beta_{SMB}^L R_{SMB,t} + \beta_{HML}^L R_{HML,t} + \beta_{MOM}^L R_{MOM,t} + \beta_{SOV}^L R_{SOV,t}$$
$$+ g(v_{t-\tau};\gamma,c)\left[\alpha^{NL} + \beta_M^{NL} R_{M,t} + \beta_{SMB}^{NL} R_{SMB,t} + \beta_{HML}^{NL} R_{HML,t} + \beta_{MOM}^{NL} R_{MOM,t} + \beta_{SOV}^{NL} R_{SOV,t}\right] + \varepsilon_{p,t}$$

Where for $i = L$ (Linear part) or $NL$ (Nonlinear part), $\beta_M^i$ and $\beta_{SMB}^i$, $\beta_{HML}^i$, $\beta_{MOM}^i$ denote the coefficients on, respectively, the market factor and on three Fama and French and Carhart factors: small minus big firms returns, returns of high book to market firms minus low ones and a momentum factor. $\beta_{SOV}^{NL}$ is the coefficient on the average change in the Sovereign CDS of Greece, Ireland and Portugal. $\gamma$ is the slope parameter and $c$ is the threshold value of the VSTOXX. Marginal significance levels based on Newey-West covariance estimator are given in parentheses. Country codes are given in the data paragraph of Section 3.

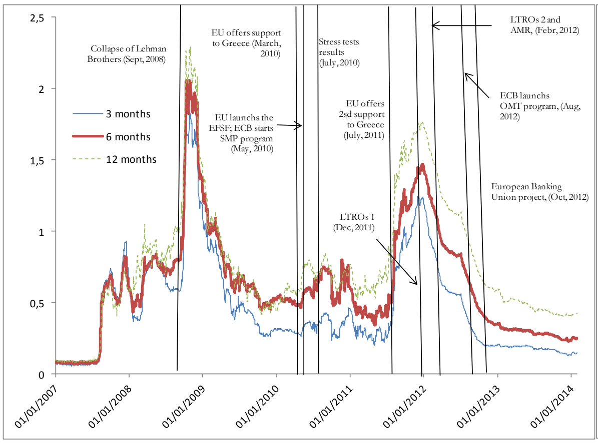
**Table A5**: Results of Misspecification tests (*p-values*)

| | *BE* | *DE* | *ES* | *FR* | *GB* | *GR* | *IE* | *IT* | *NE* | *PT* | *US* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ARCH-LM Test on residuals of the STR Model | | | | | | | | | | | |
| *ARCH(6)* | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Test of no remaining ARCH effect | | | | | | | | | | | |
| *ARCH(6)* | 0.561 | 0.447 | 0.844 | 0.676 | 0.321 | 0.820 | 0.794 | 0.708 | 0.186 | 0.305 | 0.129 |
| Tests of Autocorrelation (AR) and Remaining Nonlinearities (NL) on standardized residuals | | | | | | | | | | | |
| *AR(6)* | 0.104 | 0.048 | 0.064 | 0.814 | 0.171 | 0.788 | 0.185 | 0.511 | 0.226 | 0.440 | 0.055 |
| *NL* | 0.437 | 0.110 | 0.494 | 0.318 | 0.392 | 0.061 | 0.988 | 0.603 | 0.406 | 0.899 | 0.086 |
| Heteroskedasticity consistent tests of Autocorrelation (AR) and Remaining Nonlinearities (NL) | | | | | | | | | | | |
| *AR(6)* | >0.99 | >0.99 | >0.99 | >0.99 | >0.99 | >0.99 | >0.99 | >0.99 | >0.99 | >0.99 | >0.99 |
| *NL* | >0.99 | >0.99 | >0.99 | >0.99 | >0.99 | >0.99 | >0.99 | >0.99 | >0.99 | >0.99 | >0.99 |

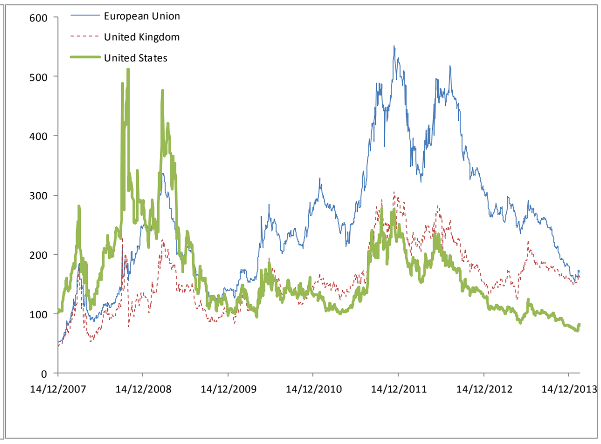
Note: This table reports the results from various misspecification tests. The results of the first ARCH-LM test (Engle, 1982) unsurprisingly reject the hypothesis of no conditional heteroskedasticity (ARCH(6)) for all countries. We therefore estimate GARCH(p,q) models for each country and compute standardized residuals to test for remaining ARCH effects, as well as for autocorrelation (Teräsvirta, 1998) and remaining nonlinearity (Eitrheim and Teräsvirta, 1996). The results confirm that most of the nonlinearities are adequately captured by the Smooth Transition Regressions and the GARCH model. As a robustness check we compute the heteroskedasticity consistent misspecification tests suggested by van Dijk et al. (2002). Though they have low power and must therefore be interpreted with caution, they confirm the previous results in that the STR specification appears to be adequate.

**Figure A1**:

**A1a**. Eurozone, Euribor/Eurepo spread



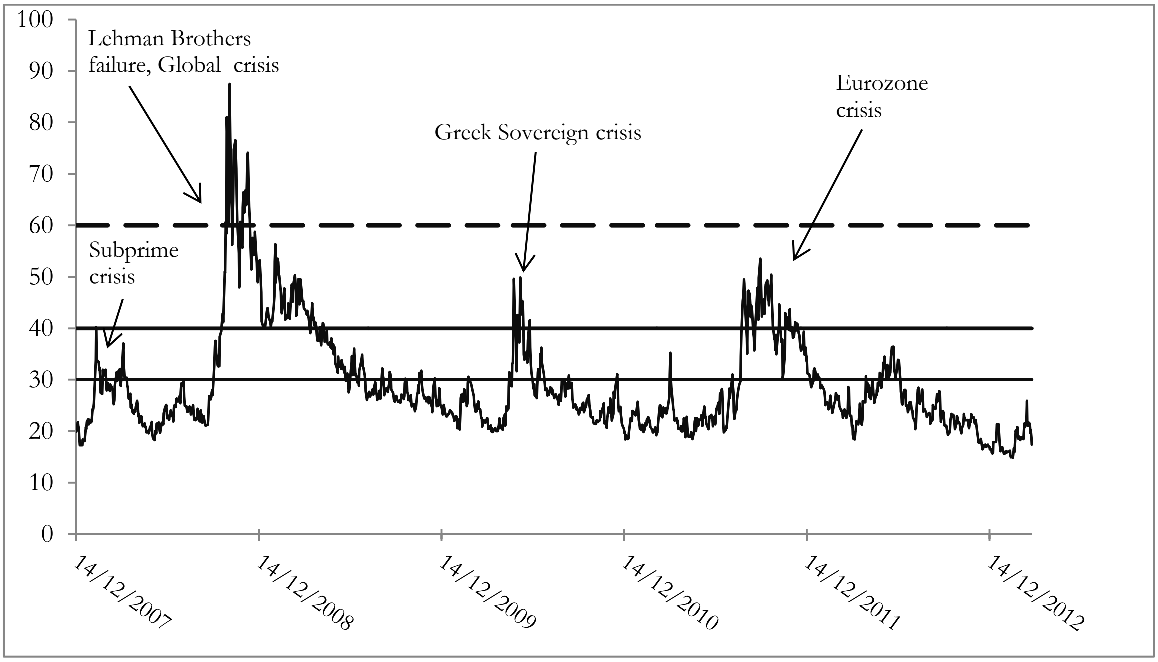

**A1b**. Banks Credit Default Swap, basis points




EFSF: European Financial Stability Facility
SMP: Securities Markets Program
LTROs: Long-Term Refinancing Operations, ECB
AMR: Alert Mechanism Report, European Commission
OMT: Outright Monetary Transactions

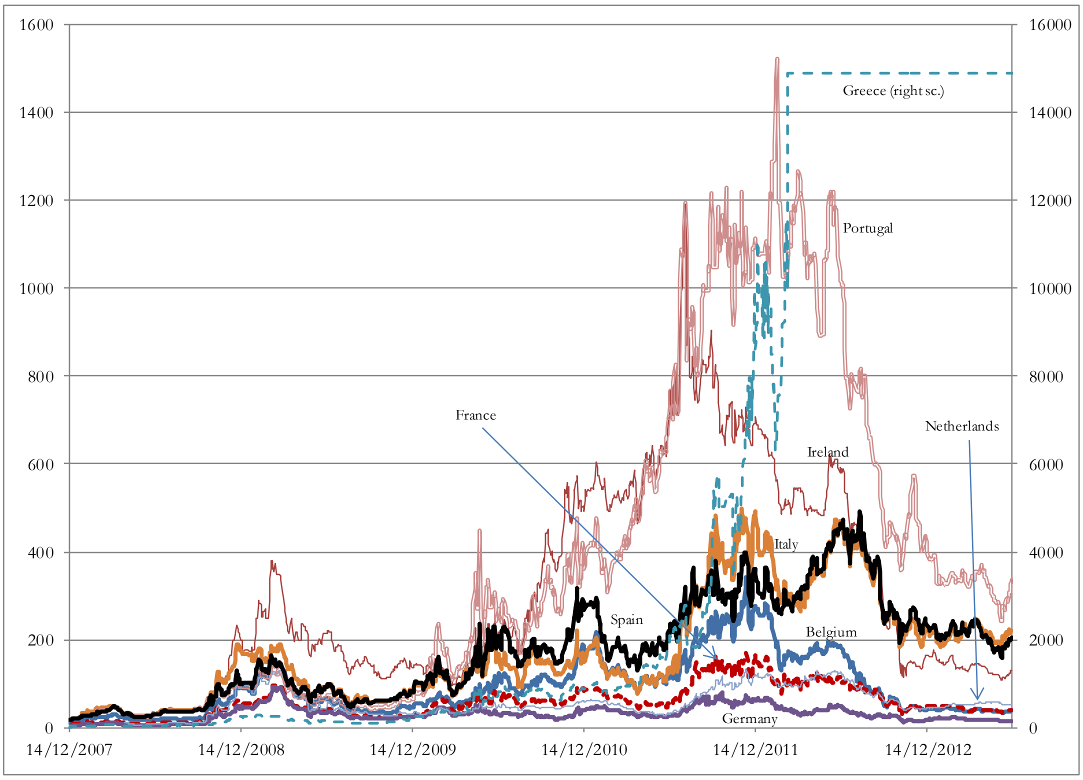
Sources: ECB, EBF, and Datastream

**Figure A2**: Implied volatility on European Stock Market (VSTOXX) and crisis episodes



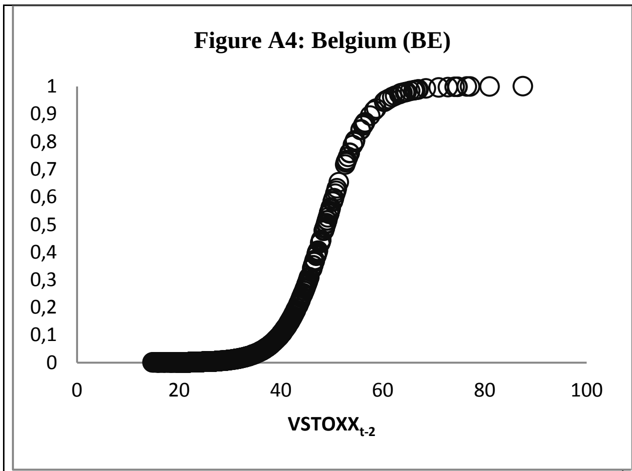

Source: Macrobond (VSTOXX)

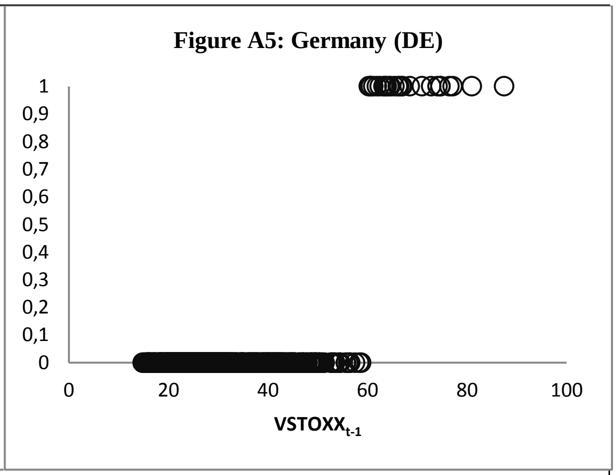
**Figure A3**: The rise of Sovereign CDSs in the eurozone




Source: Datastream.

**Figures A4-A14**: Transition functions



A6: Spain (ES)

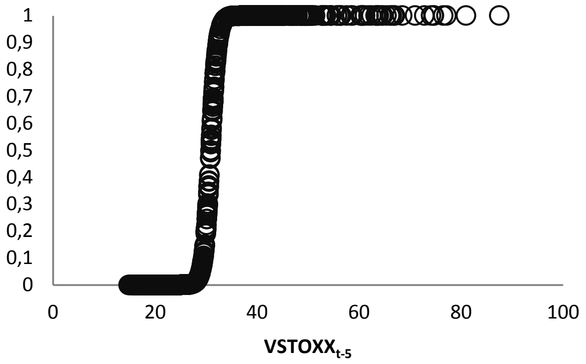



Figure A7: France (FR)

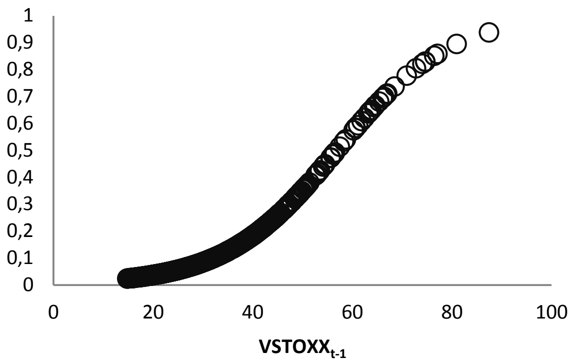



Figure A8: United Kingdom (GB)

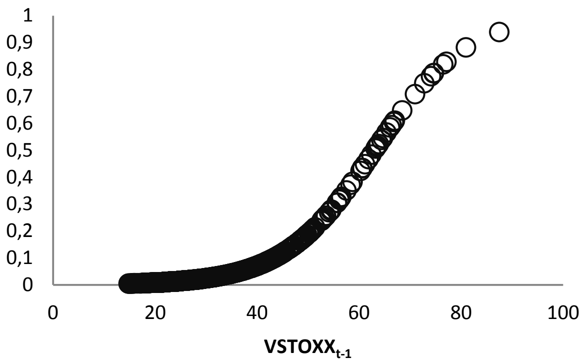



Figure A9: Greece (GR)

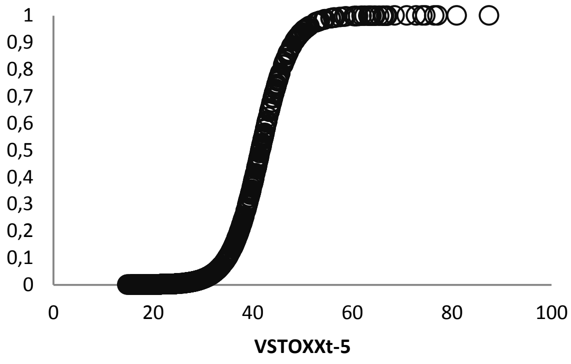



Figure A10: Ireland (IE)

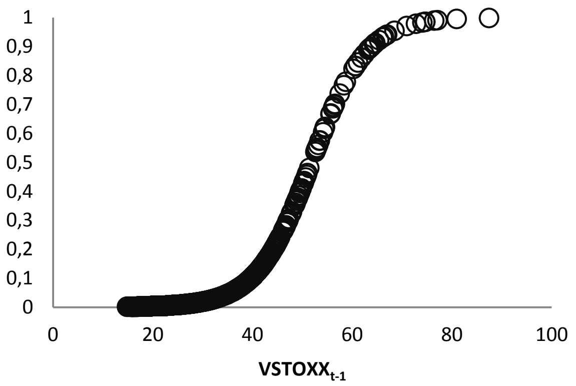



Figure A11: Italy (IT)

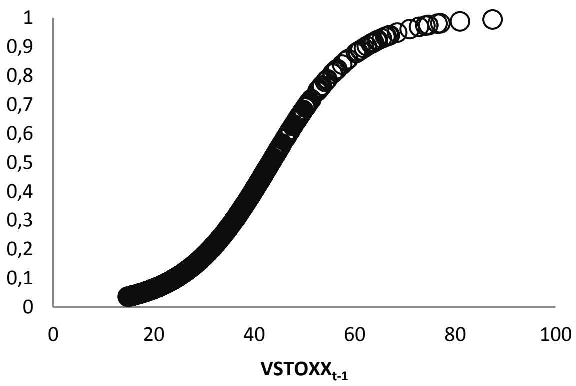


**Figure A12: Netherlands (NE)**

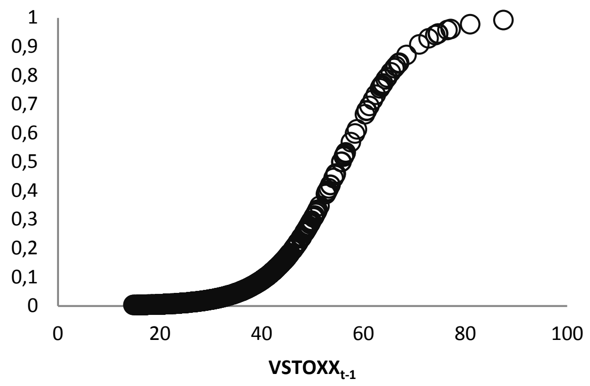



**Figure A13: Portugal (PT)**

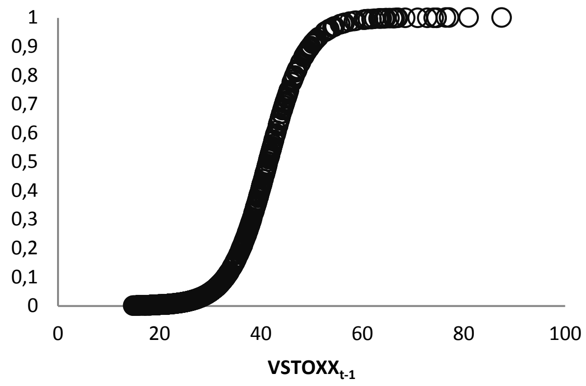



**Figure A14: United States (US)**