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Systemic Risk in Europe

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Abstract

Systemic risk may be defined as the propensity of a financial institution to be undercapitalized when the financial system as a whole is undercapitalized. Systemic risk is related to the market capitalization of the firm, its financial leverage, and the sensitivity of its equity return to market shocks. In this paper, we investigate European financial institutions and describe an econometric approach designed to measure systemic risk for non-U.S. institutions. We expand the approach developed by Brownlees and Engle (2010) to the case with several factors explaining the dynamics of financial firms returns with asynchronicity of time zones. We apply this methodology to the 196 largest European financial firms and estimate their systemic risk over the 2000-2012 period. We find that banks and insurance companies bear approximately 80% and 20% of the systemic risk in Europe, respectively. Over the period of our study, the countries with the highest levels of systemic risk are the U.K. and France, and the firms with the highest levels of systemic risk are Deutsche Bank and Barclays.

Keywords: Systemic Risk, Marginal Expected Shortfall, Multi-factor Model, Volatility, Correlation.

JEL Classification: C22, C23, C53.

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1 Introduction

The Global Financial Stability Report (2009) of the International Monetary Fund defines systemic risk as "a risk of disruption to financial services that is caused by an impairment of all or parts of the financial system and that has the potential to cause serious negative consequences for the real economy." With the recent financial crisis, interest in the concept of systemic risk has grown. The rising globalization of financial services has strengthened the interconnection between financial institutions. While this tighter interdependence may have fostered efficiency in the global financial system, it has also increased the risk of cross-market and cross-country disruptions.

The first component of systemic risk management is the assessment of systemic risk, which is typically based on the size of the financial institutions relative to the national or international financial system ("too big to fail") or on the linkages between financial institutions ("too interconnected to fail"). The second component is the detection of systemic events, which are composed of the following two elements: the shock, which can be idiosyncratic, sector-wide, regional, or systemic; and the propagation (or contagion) mechanism, which allows the shock to propagate from one institution or market to another. As the recent subprime crisis has demonstrated, systemic events are intrinsically difficult to anticipate.

Measures of systemic risk are generally based on market data, which are forward looking by their nature. Two questions may be addressed from such data because historical prices contain expectations about future events. First, how likely is it that extreme events will occur in the current financial markets? Second, how closely connected are financial institutions with one another and the rest of the economy? Obtaining the answers to those questions is at the heart of most of the recent research on systemic risk. The shape of the distribution of financial returns and the strength of the dependence across financial institutions are both essential to determine the speed of the propagation of shocks through the financial system and the level of vulnerability to such shocks.

In the aftermath of the recent financial crisis, the literature has focused primarily upon externalities across financial firms that may give rise to liquidity spirals. In particular, it became clear that network effects must be addressed to fully capture the contribution of banks to systemic risk. Thus, these measures of systemic risk consider the risk of extreme loss for a financial firm in the event of a market dislocation. Acharya, Pederson, Philippon, and Richardson (2010) and Brownlees and Engle (2010) have proposed an economic and statistical approach to measuring the systemic risk of financial firms. Following Acharya, Pederson, Philippon, and Richardson (2010), the externality that generates systemic risk is the propensity of a financial institution to be undercapitalized when the financial system as a whole is undercapitalized. In this context, there are likely to be few firms willing to absorb liabilities and acquire the failing firm. Thus leverage and risk exposure are more serious when the economy is weak. This mechanism can be captured by the expected fall in the equity value of each firm conditional on a weak economy. Then, the capital shortage for each firm is considered the source of deadweight loss to the economy. In the econometric methodology proposed by Brownlees and Engle (2010) for U.S. financial institutions, the model estimates the capital shortage that can be expected for a given firm if there is another financial crisis. The model is composed of a dynamic process for the volatility of each firm's return and its correlation dynamic with an overall equity index. Innovations are described by a non-normal (semi-parametric) joint distribution that allows the sensitivity of the firms return to extreme downturns in the equity market to be estimated.[1]

In the case of non-U.S. institutions, which are the focus of the present paper, there are several additional issues beyond the aforementioned components to measure the risk exposure: For a given firm, a financial crisis may be triggered by a world crisis (such

[1]Other measures of contagion based on the properties of the joint distribution of stock returns have been proposed. For instance, Adrian and Brunnermeier (2009) have introduced the CoVaR, i.e., the VaR of the financial system conditional on institutions being under stress. Another branch of the literature is investigating the degree of connectivity (or co-movement) among financial institutions, which is a key component of systemic risk, along the lines developed earlier by Kaminsky and Reinhart (2002). Recent papers in this field are Billio, Lo, Getmansky, and Pelizzon (2011), Kritzman, Li, Page, and Rigobon (2011), and Hautsch, Schaumburg, and Schienle (2012).

as the subprime crisis), a regional crisis (such as the European debt crisis), or even by a countrywide crisis (such as the Greek debt crisis for Greek banks). Thus, a natural extension of the previous models is a multi-factor model, where several elements may jeopardize a financial firm's health. Furthermore, the parameters of the model, in particular the sensitivity to market movements, may change over time. This in turn requires a model that allows for time-varying parameters. In this paper, we adopt the Dynamic Conditional Beta approach recently proposed by Engle (2012), in which a Dynamic Conditional Correlation (DCC) model is used to estimate the statistics that are required to compute the time-varying betas. Another issue with European data arises from the asynchronicity of the financial markets. A world crisis (for instance, initiated in the U.S. market) may affect other regions either the same day or one day later. We design a specific econometric model to address with asynchronous markets.

Our empirical analysis is based on a large set of 196 European financial firms, which includes all banks, insurance companies, financial-services firms, and real-estate firms with a minimum market capitalization of one billion euros and a price series starting before January 2000. This dataset allows us to estimate the model with data that precede the subprime crisis. We investigate several aspects of systemic and domestic risks among European financial firms. In particular, we evaluate the relative contribution of industry groups, countries, and individual firms to the global systemic risk in Europe. Our approach allows us to explicitly identify global systemically important financial institutions (G-SIFIs), using the terminology of the Basel Committee on Banking Supervision, by estimating a firm's capital shortfall in case of a worldwide shock or a Europe-wide shock. We also identify domestic systemically important financial institutions (D-SIFIs) by investigating the impact of the rescue of a firm on the domestic economy.

The remainder of the paper is organized as follows. Section 2 details the methodology adopted to estimate systemic risk measures. Section 3 presents the data and preliminary analysis. Section 4 discusses our estimates of systemic risk measures of European financial institutions, and the conclusions are presented in Section 5.

2 Methodology

In this section, we describe our model of the risk exposure of financial firms to a financial crisis. Following the approach proposed by Acharya, Pederson, Philippon, and Richardson (2010) and Brownlees and Engle (2010), we measure systemic risk as the propensity of a financial firm to be undercapitalized when the financial system as a whole is undercapitalized. This measure of systemic risk combines the value of the equity of the firm (market capitalization), the ratio of the value of its assets to the value of its equity (financial leverage), and the sensitivity of its return on equity to whole-market shocks (risk exposure). Thus, the expected capital shortfall of firm i in case of a crisis between t and $t+T$ is defined as:

$$CS_{i,t:t+T} = E_{t-1}[\theta A_{i,t+T} - W_{i,t+T} \mid Crisis_{t:t+T}], \quad (1)$$

where A_i and W_i denote the value of the assets and equity of firm i and θ is a prudential ratio of equity to assets. It represents the faction of the assets, which represents the fraction of the assets that the firm should put aside in case of a crisis.[2] Our precise definition of a crisis is provided below.

Given the discrepancy between book and market values, we adopt the following approach. The "quasi-market value" of assets in equation (1) is defined as the book value of assets (BA) plus the difference between the market value of equity (W, market capitalization) and the book value of equity (BW), i.e., $A = BA + (W - BW) = D + W$. The book value of the debt is $D = BA - BW$.[3] With this definition, equation (1) can be

[2]In the Basel II Accords, the minimum capital requirements rely on risk-weighted assets. However, the recent financial crisis has shown that risk-weighted assets may be poor measures of risk because they may lead to an underdiversification of the asset mix. The Basel Committee on Banking Supervision plans to introduce in the new Basel III Accords a leverage ratio based on total unweighted assets. As a benchmark, we adopt a capital ratio of $\theta = 8\%$. As will be clear from equation (3) below, with such a capital ratio, a firm with a leverage of 12.5 will have no capital shortfall if its market capitalization is not affected by a financial crisis.

[3]This decomposition has been widely adopted because it provides a reasonable compromise between book values, which clearly underestimate the value of equity, and market values, which would raise the issue of measuring the market value of debt.

written as:

$$CS_{i,t:t+T} = E_{t-1}[\theta D_{i,t+T} - (1-\theta)W_{i,t+T} \mid Crisis_{t:t+T}]. \tag{2}$$

Assuming that the value of the debt is not affected during the crisis and remains constant in the short run ($D_{i,t+T} = D_{i,t}$), this expression can be rewritten as:

$$CS_{i,t:t+T} = \left\{\theta(L_{i,t} - 1) - (1-\theta)E_{t-1}\left[\frac{W_{i,t+T}}{W_{i,t}} \mid Crisis_{t:t+T}\right]\right\} W_{i,t}, \tag{3}$$

where $L_{i,t} = A_{i,t}/W_{i,t}$ denotes the financial leverage, so that $D_{i,t} = (L_{i,t} - 1)W_{i,t}$.

The first term on the right-hand side of equation (3) captures the effect of the initial leverage of the firm. The second term is:

$$E_{t-1}\left[\frac{W_{i,t+T}}{W_{i,t}} \mid Crisis_{t:t+T}\right] = 1 + E_{t-1}\left[\frac{W_{i,t+T}}{W_{i,t}} - 1 \mid Crisis_{t:t+T}\right] = 1 - LRMES_{i,t:t+T},$$

where $LRMES_{i,t:t+T} = -E_{t-1}\left[\frac{W_{i,t+T}}{W_{i,t}} - 1 \mid Crisis_{t:t+T}\right]$ is the long-run marginal expected shortfall of the firm's return in the event of a financial crisis.

We now define a financial crisis as a major market decline. For a worldwide or a Europe-wide crisis, which we will call a systemic event, we consider the worst six-month market decline over a decade, which corresponds to a fall of approximately 40%. Financial markets experienced two major drawdowns of this magnitude or more over the last two decades. Eventually, LRMES is defined as:

$$LRMES_{i,t:t+T} = -E_{t-1}\left[R_{i,t:t+T} \mid R_{M,t:t+T} \leq -40\%\right], \tag{4}$$

where cumulative returns are defined as:

$$R_{i,t:t+T} = \exp\left(\sum_{j=1}^{T} r_{i,t+j}\right) - 1 \qquad \text{and} \qquad R_{M,t:t+T} = \exp\left(\sum_{j=1}^{T} r_{M,t+j}\right) - 1,$$

and $r_{i,t}$ and $r_{M,t}$ are the log-return of firm i and the log-return of the market index, respectively. The systemic risk of firm i is finally defined as positive capital shortfall:

$$SRISK_{i,t:t+T} = \max(0, CS_{i,t:t+T}). \tag{5}$$

The marginal expected shortfall of the entire financial system, i.e., the expected loss of the financial system conditional on an extreme event, is given by:

$$LRMES_{F,t:t+T} = -E_{t-1}[R_{F,t:t+T} \mid R_{M,t:t+T} \leq -40\%],$$

where $R_{F,t:t+T}$ denotes the cumulative return of the financial industry between t and $t+T$. Because the return of the industry is the value-weighted sum of the financial institutions return ($R_{F,t:t+T} = \sum_{i=1}^{N} w_{i,t} R_{i,t:t+T}$, with $w_{i,t} = W_{i,t}/W_{F,t}$), the marginal contribution of a given institution to the overall MES is simply the MES of the institution (see Brownlees and Engle, 2010):

$$\frac{\partial LRMES_{F,t:t+T}}{\partial w_{i,t}} = -E_{t-1}[R_{i,t:t+T} \mid R_{M,t:t+T} \leq -40\%] = LRMES_{i,t:t+T},$$

with $LRMES_{F,t:t+T} = \sum_{i=1}^{N} w_{i,t} LRMES_{i,t:t+T}$. This aggregation property can be used to investigate systemic risk at the country-wide level and for some categories of financial institutions.

The systemic risk measure defined above is the expected capital shortfall of a financial institution in case of a financial crisis. Thus, it measures the equity buffer that would be sufficient, *ex ante*, to face a financial crisis. In case of the default of the firm ($LRMES_{i,t:t+T} = 1$, i.e., the market capitalization goes to 0), the maximum *ex post* capital shortfall would be $\theta(L_{i,t} - 1)W_{i,t} = \theta A_{i,t}$, reflecting the firm's lack of equity. In fact, the final cost for the taxpayer in case of a bailout may be significantly larger if the government decides to endorse part of the debt of the defaulting firm. We also note that a lower bound for the capital shortfall can be obtained by assuming that the crisis does not affect the market capitalization of the firm ($LRMES_{i,t:t+T} = 0$), in which case we find $(\theta L_{i,t} - 1)W_{i,t}$. A crude measure of the range of the SRISK measure is therefore given by $[(\theta L_{i,t} - 1)W_{i,t}\ ;\ \theta(L_{i,t} - 1)W_{i,t}]$. The size of the range is $(1 - \theta)W_{i,t}$. Thus, for highly leveraged firms (low market capitalization), the SRISK measure is relatively insensitive to the LRMES estimates and depends primarily on financial leverage. Conversely, the SRISK of a firm with low leverage can be significantly affected by a change in its LRMES.

2.1 Econometric Methodology

There are substantial differences across European countries in terms of macroeconomic dynamics, fiscal and monetary policy and regulation. For this reason, as opposed to the U.S., a finer distinction of what drives the risk of a financial firm is required. In our stratification, we allow for the following three drivers of a firms return: the country-wide index ($r_{C,t}$), European index ($r_{E,t}$), and world index ($r_{W,t}$). A further complication stems from the asynchronicity of time zones. The stock market of a given country may be affected by a shock on the world index one day later, if the shock is initiated late in the U.S. or overnight in Asia. For these reasons, our system includes five series, $r_t = \{r_{i,t}, r_{C,t}, r_{E,t}, r_{W,t}, r_{W,t-1}\}$. The objective of the model is to capture the dependence of the return of firm i with respect to the drivers. Our econometric approach aims at capturing this dependence by designing a factor model with time-varying parameters, time-varying volatility, and a general, non-normal dependence structure for the innovations.

We begin with the following recursive multi-factor model with time-varying parameters, after having preliminarily demeaned all return series:

$$
\begin{aligned}
r_{i,t} &= \beta_{i,t}^{C}\ r_{C,t} + \beta_{i,t}^{E}\ r_{E,t} + \beta_{i,t}^{W}\ r_{W,t} + \beta_{i,t}^{L}\ r_{W,t-1} + \varepsilon_{i,t} \\
r_{C,t} &= \beta_{C,t}^{E}\ r_{E,t} + \beta_{C,t}^{W}\ r_{W,t} + \beta_{C,t}^{L}\ r_{W,t-1} + \varepsilon_{C,t} \\
r_{E,t} &= \beta_{E,t}^{W}\ r_{W,t} + \beta_{E,t}^{L}\ r_{W,t-1} + \varepsilon_{E,t} \\
r_{W,t} &= \beta_{W,t}^{L}\ r_{W,t-1} + \varepsilon_{W,t},
\end{aligned}
$$

where the L superscript corresponds to the lagged world-market index. The parameters of the model are estimated using the Dynamic Conditional Beta approach proposed by Engle (2012). The estimation is performed as follows. We assume that, conditional on the information set at date $t-2$, the return process has mean $E_{t-2}[r_t] = 0$ and covariance matrix $V_{t-2}[r_t] = H_{t/t-2}$. The conditional covariance matrix H_t is estimated by a DCC model (Engle and Sheppard, 2001; Engle, 2002) as:

$$H_t = D_t^{-1/2} \Gamma_t D_t^{-1/2}, \tag{6}$$

$$\Gamma_t = \left(\mathrm{diag}\left(Q_t\right)\right)^{-1/2} Q_t \left(\mathrm{diag}\left(Q_t\right)\right)^{-1/2}, \tag{7}$$

$$Q_t = \Omega + \delta_1 Q_{t-1} + \delta_2 \left(\eta_{t-1} \eta_{t-1}'\right), \tag{8}$$

where $\eta_t = \{\eta_{i,t}, \eta_{C,t}, \eta_{E,t}, \eta_{W,t}, \eta_{W,t-1}\} = D_t^{-1/2} r_t$ is the vector of normalized returns, $\mathrm{diag}(Q_t)$ denotes a matrix with zeros, except for the diagonal that contains the diagonal of Q_t, and D_t is the diagonal matrix with the conditional variances of r_t on its diagonal and zero elsewhere. Parameters δ_1 and δ_2 are restricted to ensure that the conditional correlation matrix, Γ_t, is positive definite. Armed with this model, we estimate the parameters associated with firm i return as:

$$\beta_{i,t} = \begin{pmatrix} \beta_{i,t}^C \\ \beta_{i,t}^E \\ \beta_{i,t}^W \\ \beta_{i,t}^L \end{pmatrix} = \begin{pmatrix} H_{CC,t} & H_{CE,t} & H_{CW,t} & H_{CL,t} \\ H_{CE,t} & H_{EE,t} & H_{EW,t} & H_{EL,t} \\ H_{CW,t} & H_{EW,t} & H_{WW,t} & H_{WL,t} \\ H_{CL,t} & H_{EL,t} & H_{WL,t} & H_{LL,t} \end{pmatrix}^{-1} \begin{pmatrix} H_{iC,t} \\ H_{iE,t} \\ H_{iW,t} \\ H_{iL,t} \end{pmatrix}.$$

The other sets of parameters, $\beta_{C,t}$, $\beta_{E,t}$, and $\beta_{W,t}$, are estimated accordingly.

The error terms $\varepsilon_t = \{\varepsilon_{i,t}, \varepsilon_{C,t}, \varepsilon_{E,t}, \varepsilon_{W,t}\}$ are uncorrelated across time and across series, but may be non-linearly dependent both in the time series (such as heteroskedasticity) and in the cross-section (such as tail dependence). To deal with heteroskedasticity, we assume a univariate asymmetric GARCH model (Glosten, Jagannathan, and Runkle, 1993):

$$\varepsilon_{k,t} = \sigma_{k,t}\ z_{k,t}, \tag{9}$$

where

$$\sigma_{k,t}^2 = \omega_k + \alpha_k \varepsilon_{k,t-1}^2 + \beta_k \sigma_{k,t-1}^2 + \gamma_k \varepsilon_{k,t-1}^2 1_{\left(\varepsilon_{k,t-1} \leq 0\right)}, \tag{10}$$

for $k \in \{i, C, E, W\}$. The innovations process $z_t = \{z_{i,t}, z_{C,t}, z_{E,t}, z_{W,t}\}$ is such that $E[z_t] = 0$ and $V[z_t] = I_4$. It is commonly accepted that the conditional distribution of stock market returns is fat-tailed and asymmetric. To capture these features, the innovations are assumed to have a univariate skewed t distribution, $z_{k,t} \sim f(z_{k,t}; \nu_k, \lambda_k)$, where f denotes the pdf of the skewed t distribution, with ν_k the degree of freedom and λ_k the asymmetry parameter (see Jondeau and Rockinger, 2003).

Measures of systemic risk are based on marginal expected shortfalls (equation (4)), which rely on the dependence structure of the innovation processes. Although the innovations z_t have been preliminarily orthogonalized, they cannot a priori be assumed to be independent.[4] Therefore, we must estimate a joint distribution that allows us to capture the possible non-linear dependencies across innovation processes. A convenient approach is to describe the joint distribution of z_t with a copula. For this purpose, we define $u_t = \{u_{i,t}, u_{C,t}, u_{E,t}, u_{W,t}\}$ as the margin of z_t with $u_{k,t} = F(z_{k,t}; \nu_k, \lambda_k)$, where F is the cdf of the skewed t distribution with parameters (ν_k, λ_k). The copula is then the joint distribution of u_t, denoted by $C(u_t)$. After investigating several alternative copulas, we eventually selected the t copula, which has been found to capture the dependence structure of the data very well. It accommodates tail dependence and its elliptical structure provides a convenient way to address with large-dimensional systems. The cumulative distribution function (cdf) of the t copula is defined as:

$$C_{\Gamma,\bar{\nu}}(u_{i,t}, ..., u_{W,t}) = t_{\Gamma,\bar{\nu}}(t_{\bar{\nu}}^{-1}(u_{i,t}), ..., t_{\bar{\nu}}^{-1}(u_{W,t})), \tag{11}$$

[4] It should be mentioned that the Dynamic Conditional Beta model is likely to capture more than the mere linear dependence between the variables. It is not clear, however, how much of the non-linear dependence is left in the innovation process.

where $t_{\bar{\nu}}$ is the cdf of the univariate t distribution with degree of freedom $\bar{\nu}$ and $t_{\Gamma,\bar{\nu}}$ is the cdf of the multivariate t distribution with correlation matrix Γ and degree of freedom $\bar{\nu}$.

To summarize, our model combines a DCC model for the dynamic of the beta parameters, univariate GARCH models for the dynamic of the volatility of the error terms, and a t copula for the dependence structure between the innovations. To deal with the possible time variability of (some of) the model parameters, we estimate the model over a rolling window of ten years of data as soon as a new observation is made available.

The estimation strategy is worth describing. Although we have a the large number of models to estimate (196 financial institutions), the component that corresponds to the interaction between the European and world markets is common to all of models. Therefore, we perform the estimation recursively as follows. We begin with the estimation of the dynamic of European and world markets, i.e., the model for $(r_{E,t}, r_{W,t}, r_{W,t-1})$. We estimate the DCC model for these series and the corresponding time-varying beta parameters. We also estimate the univariate GARCH processes for their error terms $(\varepsilon_{E,t}, \varepsilon_{W,t})$ and the parameters of the t copula. We call this model the *International model*. Next, we introduce the stock market return, $r_{C,t}$, for a given country (say, Austria) and estimate the parameters that correspond to this series, taking as given the parameters of the European and world market returns (*Country model*). Finally, for all of the Austrian financial institutions, we introduce the firm i return, $r_{i,t}$, and estimate the parameters corresponding to this series, taking as given the parameters of the Austrian, European, and world market returns (*Firm model*). This approach has three advantages. First, it is coherent with the recursive structure of the model. Second, it ensures that the dynamics of the European and world market returns are the same for all sub-models. Third, it allows for a relatively fast estimation of the complete model and LRMES.

2.2 Measuring Long-run Marginal Expected Shortfall

We now turn to the estimation of the long-run MES ($LRMES_{i,t:t+T}$). Brownlees and Engle (2010) advocated for two complementary approaches to estimate the LRMES. The first approach consists of estimating the LRMES directly as the expected return of the firm in case of a 40% semiannual decline in the market return. In the second approach, the LRMES is based on the expected return of the firm in case of a (relatively modest) 2% decline in the daily market return, which is then extrapolated to match a "once-per-decade" crisis. For this study, we implemented both approaches and found that they provide essentially the same systemic risk measures. To save space, we describe the methodology and report the results of the first approach only.

Directly estimating the LRMES relies on the simulation of the model over T periods using all information available at date t. As for the estimation strategy, our simulation strategy takes advantage of the recursive structure of the model. We start by simulating the International model over T periods (125 daily observations, for a six-month period). To this end, we draw a sample s of $(u_{E,\tau}^{(s)}, u_{W,\tau}^{(s)})_{\tau=t,\cdots,t+T}$ from the t copula and then deduce the innovation terms $(z_{E,\tau}^{(s)}, z_{W,\tau}^{(s)})$ from the skewed t distribution. Using the GARCH estimates of the volatility, we compute the errors terms $(\varepsilon_{E,\tau}^{(s)}, \varepsilon_{W,\tau}^{(s)})$. We then estimate the dynamic betas, which depend on the correlation matrix and therefore on $\varepsilon_{\tau}^{(s)}$. Eventually, we recover a six-month time series of European and world market returns, $(r_{E,\tau}^{(s)}, r_{W,\tau}^{(s)})$. The cumulative returns at $t + T$ tell us whether we have a crash (if the European or world cumulative returns are below -40%) over this simulated sample s. If we do not have a crash, we simulate a new series. If we do have a crash, then we continue with the Country model. We simulate the $u_{C,\tau}^{(s)}$ from the t copula (using the same chi-square in the simulation of the t random variable to keep the same dependence structure between the three shocks $u_{C,\tau}^{(s)}$, $u_{E,\tau}^{(s)}$, and $u_{W,\tau}^{(s)}$) and proceed as before to obtain the country market return. Finally, we continue with the simulation of the firm return using the same methodology.

It is worth emphasizing that the recursive structure is critical in the simulation step to obtain systemic risk measures in a decent amount of time. To obtain an accurate estimate of the marginal expected shortfall of the firm return conditionally on a market crash, ma ny draws of the International model are required to simulate a sufficient number of crashes.[5]

Eventually, the LRMES of firm i conditional on a world shock is estimated by:

$$LRMES^{(W)}_{i,t:t+T} = \frac{-1}{\sum_{s=1}^{S} \mathcal{I}(R^{(s)}_{W,t:t+T} \leq -40\%)} \sum_{s=1}^{S} R^{(s)}_{i,t:t+T} \times \mathcal{I}(R^{(s)}_{W,t:t+T} \leq -40\%), \quad (12)$$

where $\mathcal{I}(x) = 1$ if x is true and 0 otherwise. This approach provides very accurate estimates of the true expectation when the number of simulated data is sufficiently large. In our empirical work, we use $S = 50'000$ draws. We eventually deduce the SRISK of firm i as the positive value of the capital shortfall conditional on a world or European crisis as:

$$CS^{(W)}_{i,t:t+T} = \left\{ \theta(L_{i,t} - 1) - (1-\theta) LRMES^{(W)}_{i,t:t+T} \right\} W_{i,t}. \quad (13)$$

We proceed in a similar way for a European shock to obtain $LRMES^{(E)}_{i,t:t+T}$ and $CS^{(E)}_{i,t:t+T}$.

For the domestic crisis, we should account for the differences in the volatility of the market returns across countries. In fact, a semiannual 40% crash would be perceived as much more severe in Switzerland than in Hungary because the annual market volatilities for these countries were 17% and 32%, respectively, over the last ten years. We therefore use a shock of 1.6 times the annualized volatility of the domestic market return over the last ten years, which corresponds to a semiannual 40% shock on average. A shock of 1.6 times the annual market volatility corresponds to a market decline of 27% for the Swiss market, 52% for Hungary, and a maximum of 60% for Turkey. The LRMES conditional

[5]If we had to simulate the model for all the firms, the computation burden would be too heavy to estimate systemic risk measures. To give an order of magnitude of the computation burden, estimating the systemic risk for all firms for one date takes approximately 20 minutes for the model estimation and the simulation steps, whereas it would take several days if we had to estimate and simulate the complete model for all of the firms.

on a country shock is represented as:

$$LRMES^{(C)}_{i,t:t+T} = \frac{-1}{\sum_{s=1}^{S} \mathcal{I}(R^{(s)}_{C,t:t+T} \leq -1.6\ \sigma_C)} \sum_{s=1}^{S} R^{(s)}_{i,t:t+T} \times \mathcal{I}(R^{(s)}_{C,t:t+T} \leq -1.6\ \sigma_C), \quad (14)$$

where σ_C is the annualized volatility of the daily domestic market return computed over the last ten years. Eventually, we define the domestic risk (DRISK) as the positive value of the capital shortfall conditional on a country-wide crisis, defined as in equation (13). To allow for a comparison across countries, we may express the DRISK as a percentage of current gross domestic product (GDP). A large DRISK means that rescuing the firm would incur a large cost for the taxpayer as a percentage of the GDP.

3 European Data

3.1 Data

Our sample is the set of large financial institutions in Europe. We include all firms with a minimum market capitalization of one billion euros (as of end of 2011) and a price series that started before January 2000. The entire sample starts in January 1990 (when available) and ends in August 2012. For comparison purposes, all series are converted into euros. The data set includes daily data (stock returns and market capitalizations, from Datastream) and quarterly data (book value of the assets and equity, from Compustat).

In our sample, there are 72 banks, 36 insurance companies, 53 financial-services firms, and 35 real-estate firms. There are 45 financial firms in the U.K., 22 in France, 21 in Switzerland, 18 in Sweden, and 14 in Germany. The largest market capitalizations at the end of August 2012 are HSBC Holdings (126.2 billion euros), Banco Santander (56 billion), and Sberbank (49.4 billion). The largest insurance company is Allianz (39.6 billion), the largest financial-services firm is ING (23.3 billion), and the largest real-estate firm is Unibail-Rodamco (14.9 billion). The cumulative market capitalization for the 196 institutions is 1'448 billion euros, with a median capitalization of 2.9 billion euros.

Figure 1 shows a comparison of the cumulative performances of the global European market and of the components of the financial institutions index. The European market index has experienced two drawdowns above 50%. The first one occurred over the period 2000-2003 with the Internet bubble burst, and the second one occurred over the period 2007-2009 with the subprime crisis. Our threshold of a 40% crash per decade is consistent with these numbers.

Financial institutions offer widely varying patterns. Banks and insurance companies were in line with the European market and outperformed the other financial groups until 2001. At that time, insurance companies experienced their most severe drawdown (79% between November 2001 and March 2003) and then underperformed the other groups. During the subprime crisis, bank stocks suffered a dramatic fall, with a drawdown of 82%. Financial-services and real-estate firms show similar dynamics, with a significant underperformance during the 1990s and catching up with the market trend just before the subprime crisis.

As **Table 1** confirms, banks and insurance companies have similar performances over the entire period (with an average annualized return of 1.9% and 1.7%, respectively). Financial-services firms slightly outperform the other categories (3.1%), while real-estate firms underperform (1.5%). Banks and insurance companies are also characterized by high volatility and a positive skewness, whereas financial-services and real-estate firms have relatively low volatility and a negative skewness. For all groups, the distribution of returns has fat tails.

One key ingredient of systemic risk measures is the firm's financial leverage, defined as the quasi-market value of a firm's assets divided by the market value of its equity. It is notable that the leverage measures of European institutions are hardly comparable with those of U.S. institutions. The reason is that the firms in the two zones are currently under two different accounting standards: Generally Accepted Accounting Principles (GAAP) in the U.S. and International Financial Reporting Standards (IFRS) in Europe. Based on the zone to which a bank belongs, derivatives are reported differently on the balance sheet. Under the U.S. GAAP, derivatives are generally reported as net rather than gross. Banks are allowed to net their derivatives transactions if they are subject to a legally enforceable Master Netting Agreement (MNA). In addition, banks are allowed to present their balance sheet on a net basis (offsetting). In contrast, under the IFRS standard, netting and offsetting are typically not possible. The ability to offset is limited even for derivatives traded with the same counterparty with an MNA. Additionally, offsetting requires that the bank intended to settle on a net basis or simultaneously, which is typically not the case.

For these reasons, the balance sheet of U.S. banks presents derivatives on a net basis, meaning that derivatives represent a negligible part of the assets, whereas the balance sheet of European banks reports derivatives on a gross basis. Because banks do not publish their balance sheet simultaneously under the two standards, it is difficult to clearly measure the effect on the resulting leverage. Some crude estimates suggest that the total assets (and therefore the leverage) of large U.S. banks (which are highly active in derivatives markets) would be 40-60% larger under IFRS than under U.S. GAAP. Although crude, these numbers partly explain why the leverage measures we report in this paper are large according to U.S. numbers.

Figure 2 reports the evolution of financial leverage and market capitalization by industry groups. Between 2000 and 2007, banks and insurance companies had similar, relatively low, leverage (approximately 13.5). Between 2002 and 2003, the leverage of insurance companies was even higher than that of banks. Over the more recent period, however, leverage in the banking industry rocketed to an average of 31 in August 2012, after a peak of 44 in mi-2009. During the same period, leverage increased to 20 for insurance companies. For the other two groups, leverage is moderate. There is an upward trend for financial services and the current average level is at 6.9. For real-estate firms, leverage is limited, with a maximum of 4 during the subprime crisis. It is currently only slightly over 2.

We notice that the leverage ensuring no capital shortfall is 12.5 for a capital ratio of $\theta = 8\%$. Financial-services and real-estate firms have leverage far below this level and consequently we do not expect large measures of systemic risk for these institutions even if the sensitivity to global shocks may be large. In contrast, banks and insurance companies are well above this threshold and therefore would show capital shortfall in the event of a financial crisis even if their market capitalization were not affected by the crisis.

3.2 Model Estimation

Given the large number of firms under consideration, we do not report individual parameter estimates and associated dynamics for all the firms. Instead, we focus on results aggregated by industry groups and countries and on certain individual results for the banks (Deutsche Bank and Barclays), insurance company (AXA), and financial-services firm (ING Group) with the highest levels of systemic risk. This approach permits us to illustrate the main features common to all financial institutions and the main differences that appear between banks and insurance companies.

We start with the estimation of the model parameters based on the last ten years of data. As **Table 2** (Panel A) reveals, the differences between industry groups are relatively small. The parameters driving individual variances are similar across industry groups with a volatility persistence ranging between 0.98 and 0.99. The univariate distributions have fat tails, as expected. The degree of freedom ν of the skewed-t distribution ranges between 4.3 and 5.5, reflecting large levels of kurtosis, as reported in Table 1. The asymmetry parameter λ is found to be positive on average for all categories, suggesting a positive skewness for the distribution of individual innovations. Finally, the dependence structure is described by a t copula with a degree of freedom $\bar{\nu}$ between 16 and 18.5. This result suggests that the Dynamic Correlation Beta multi-factor model is able to capture a significant part of the dependence across the series but that the t copula is needed to capture the tail dependence remaining in the innovation processes.[6]

Figure 3 presents the dynamic of the beta parameters in the International model, i.e., between the European and world markets, and for certain Country models. The lagged world return has a relatively stable and positive effect on the world return ranging between 0 and 0.15. This effect is the result of the asynchronicity of time zones. The aggregate effect of the (current and lagged) world return on the European market is close to one, with fluctuations between 0.7 and 1.3. However, during certain periods (such as 2008-2009), the relative weight of the lagged return increases. Contemplating the betas for certain country market returns, we note significant differences across countries. For the U.K., in particular, the weight of the European market decreased during the 2011-2012 period, whereas the weight of the world market increased. We note the opposite for the French and German markets, which reflects the importance of the debt crisis in Greece for countries belonging to the euro area.

The (time-varying) sensitivity of stock returns to their main drivers (conditional betas) is estimated via the DCC model described in Section 2.1. In the summary statistics reported in Table 2 (Panel B), we note that the main driver of a firm's return is the domestic market but that there are differences between the categories. Banks and insurance companies are more sensitive to this market (median beta of 0.93 and 0.73, respectively), whereas real-estate firms are much less sensitive (median of 0.34). The European market also plays an important role (with a sensitivity between 0.05 and 0.3). Finally, the sensitivity of firms to the (current and lagged) world return is typically positive, with a cumulative effect between 0 and 0.15. We notice that, on average, a firm's current return is more affected by the lagged world return than by the current return.

Figure 4 displays the beta dynamics for the four firms under scrutiny. As mentioned previously, the domestic market is the main driver, although its role is more pronounced

[6]We do not report the correlation matrix of the copula to save space. As expected, given that we preliminarily filtered for the time-varying linear correlation between returns (through the Dynamic Conditional Beta), the correlation matrix Γ_t is close to the identity matrix.

for the insurance company (AXA) and financial-services firm (ING). In addition, we observe that the sensitivity to the domestic market has increased for all firms in 2008-2009 and, to a lesser extent, in 2011-2012. Comparing Deutsche Bank and Barclays illustrates that banks' return may be driven by a different combination of factors. Both banks depend primarily on the domestic market. However, the second factor is the world market for Deutsche Bank and the European market for Barclays.

4 Analysis of Systemic Risk

4.1 Systemic Risk across Industry Groups

We now turn to the measures of systemic risk. Statistics on the main components (market capitalization, leverage, and LRMES) and the systemic risk are reported in **Table 3** for the four industry groups. The dynamic of LRMES and SRISK are displayed in **Figure 5** for a world crash (black line) and European crash (dotted blue line).

The LRMES estimates display different patterns across groups and over time. A 40% semiannual decline of the world market implies an average expected loss of approximately 40% for banks and insurance companies but only 27% and 13% for financial-services and real-estate firms, respectively. These numbers have varied substantially over the recent period for banks and insurance companies. The expected loss after a world shock was in the range of 27% to 30% between 2000 and 2007 but rove above 37% after 2008. We also observe that the LRMES of insurance companies actually increased for the first time in 2002-2003, with a higher average sensitivity to world shocks than in 2008-2009. Changes in LRMES are also significant for financial-services and real-estate firms, increasing from 25% to 31% for the former and from 11% to 17% for the latter. This increase for all industry groups reflects the fact that financial institutions have become more dependent on market trends during difficult economic times.

If we turn to the effect of a shock on the European market, we note that financial firms are generally more sensitive to European shocks than to world shocks of the same magnitude. For instance, the LRMES of banks is 31% with respect to a world shock and 37% with respect to a European shock over the entire sample. This sensitivity has also increased over the recent period from 33% (2000-2007) to 43% (2008-2012) for banks. This evolution is confirmed by Figure 5.

The systemic risk measure combines the various effects described above, including the sensitivity to world/European shocks and the fragility (measured by leverage) of financial firms. Not surprisingly, we note again that banks and insurance companies have suffered from substantial systemic risk over the entire period (on average, 741 and 227 billion euros, respectively), whereas the expected capital shortfalls of financial-services and real-estate firms have been barely affected by the recent events. On average, banks and insurance companies account for 80% and 18% of the systemic risk across European financial firms, respectively.

If we consider the recent period (2008-2012), we find that the exposure of financial institutions has strongly increased compared to the 2000-2007 period, as expected: in fact, it has been multiplied by 3.9 for banks and by 1.8 for insurance companies. The total exposure of the 196 largest financial institutions in Europe has increased from an average of 533 billion euros between 2000 and 2007 to 1,736 billion euros between 2008 and 2012. At the end of the study period (August 30, 2012), the total exposure was 2,000 billion euros.[7]

If we now consider a European crisis, we find that the implied capital shortfall is slightly above the capital shortfall that would occur after a world shock of the same magnitude. Over the 2000-2007 period, the average SRISK measure for banks was 382 billion euros after a European crisis, as opposed to 353 billion euros after a world crisis. The most recent estimates (August 2012) were 1,668 and 1,628 billion euros, respectively. These numbers reveal that a European crash would have at least as severe consequences

[7] This number is significantly larger than the 705 billion dollars for U.S. financial firms for the same date, as reported on the VLab website at Stern School of Business (http://vlab.stern.nyu.edu/welcome/risk). As mentioned above, the two numbers rely on different accounting rules regarding derivatives. However, even after correction for the difference in leverage due to derivatives treatment, the cumulated systemic risk of European firms is much higher than for U.S. firms.

for European banks as a world crash. We observe similar patterns for insurance companies. The relatively thin difference between the world and European SRISK can be explained by the large correlation between the two types of shocks under consideration.

4.2 Systemic Risk across Countries

In **Table 4**, we report the average leverage, LRMES, and systemic risk measures for the eight riskiest countries. The leverage presents significantly large differences across countries because countries do not have the same proportion of banks and insurance companies and because there are great differences in terms of leverage across countries within the same industry group. Over the entire sample, Germany and France share higher leverage, whereas Spain, Sweden, and the U.K. have relatively low leverage levels (see **Figures 6 to 8**). As of August 2012, the average leverage is as high as 41 for France, and 36 for Italy and Germany, whereas it is only 15 for Sweden and 21.5 for Switzerland and Spain.

The LRMES measures are noteworthy across countries over the recent period. The 2008-2012 period has been characterized by a sharp increase in LRMES with respect to the world crisis. The largest values are obtained for the Netherlands and U.K. (44% and 40%, respectively). These numbers have decreased over the recent period for the non-euro countries (the U.K. and Switzerland) but increased for the more fragile countries of the euro area (from 37% to 44% for Spain and from 31% to 36% for Italy).

Another important characteristic of the SRISK measure is its relation to market capitalization. SRISK measures the fraction of the capital requirement that is not covered by the current market capitalization. Thus, it may be below or above the current market capitalization depending on the severity of the firm's situation. As Table 4 reveals, over the 2000-2007 period, SRISK was well below the market capitalization for most countries, representing only 28% of the market capitalization for Spain and up to a maximum of 122% for France. By the end of August 2012, the situation had dramatically changed because SRISK has rocketed while the market capitalization has plummeted. At present, SRISK represents a minimum of 109% of the market capitalization for Switzerland and a maximum of 279% for France. This result clearly illustrates that market capitalization is only a crude measure of systemic risk, which may be severely underestimated in bad times. Another financial crisis would imply a significant cost for the taxpayer in case of a rescue by the government that would greatly exceed the current market capitalization of the rescued firms.

All in all, over the last decade, the country with the highest systemic risk is France (229 billion euros on average), followed by the U.K. (210 billion) and Germany (181 billion). Although British firms have relatively low leverage, they have high LRMES and large market capitalization. During the recent crisis, the leverage and LRMES increased in all countries, so the systemic risk has also dramatically increased. Between 2008 and 2012, the U.K. ranked first (436 billion) in terms of overall systemic risk, followed by France (422 billion) and Germany (259 billion). As of the end of August 2012, the systemic risk estimates are as high as 527 and 465 billion euros for the U.K. and France, together contributing approximately 50% of the total exposure of European financial firms.

4.3 Ranking of Financial Institutions

The last step of our study of systemic risk is ranking European financial firms. **Table 5** shows the ranking for the last day of our sample, August 30, 2012. On that day, the five riskiest institutions were Deutsche Bank (162 billion euros), Barclays (141 billion euros), Crédit Agricole (134 billion euros), BNP Paribas (129 billion euros), and Royal Bank of Scotland (125 billion euros).

The comparison between BNP Paribas and Crédit Agricole clearly shows that systemic risk may have different sources. BNP has relatively low leverage and relatively large market capitalization (44 and 43 billion euros, respectively). In contrast, Crédit Agricole has an extremely large leverage level and small market capitalization (152 and 12 billion euros, respectively). We also notice that the two banks with the largest market capitalization (HSBC and Banco Santander) are only ranked 8th and 11th. The reason for this relatively low ranking is that they both have very low leverage and low LRMES compared to other major banks.

Insurance companies exhibit less systemic risk than banks. The most important insurance companies are AXA (15th, 44 billion euros) and Allianz (22nd, 27 billion euros). Both companies have high LRMES and relatively large market capitalization; however, their leverage is low compared to large banks. The only financial-services firm in the top 25 is ING Group, ranked 7th (85 billion euros).

The ranking of financial institutions in terms of systemic risk reported in Table 5 is consistent with the list of G-SIFIs produced by the Financial Stability Board (2011) and based on the methodology adopted by the Basel Committee on Banking Supervision (2011). The list of the FSB contains 17 European banks. From this pool, 15 are listed among the 16 riskiest institutions in our ranking, which also includes insurance companies. The two banks not listed in our ranking are special cases: Banque Populaire Caisse d'Epargne is a non-listed cooperative bank, whereas Dexia has been bailed out several times since 2008.

4.4 Fragility of the European Financial System

Estimates of the SRISK measures discussed above have two important implications. First, the European financial system is significantly more fragile than the U.S. system because of the size of the total capital shortfall in case of a new (world or European) financial crisis. Second, and perhaps more importantly, the SRISK of large European financial institutions is large compared to the size of the countries. This issue is related to the notion of domestic systemically important banks (D-SIBs). The Basel Committee on Banking Supervision (2012) defines D-SIBs as financial institutions whose failure may have systemic implications on the domestic economy. D-SIBs are typically banks whose SRISK will be very high in comparison to the GDP.

Table 6 reports the ranking of D-SIFIs, sorted by decreasing ratios of SRISK to nominal GDP (as of August 30, 2012). As before, the shock corresponds to a 40%

semiannual decline of the world market return. This ranking allows us to identify some firms that may not be too risky at the European level (because their size is limited) but that are very risky at the domestic level. Not surprisingly, the riskiest banks are based in relatively small countries. The SRISK of the five riskiest banks represents more than 9% of the GDP (UBS and Credit Suisse in Switzerland, ING Group in the Netherlands, Danske Bank in Denmark, and Nordea Bank in Sweden). These institutions are in the second tier of the G-SIFIs ranking (between 7th and 20th). Rescuing these banks would have a huge cost for taxpayers. In addition to being too big to fail, these banks are also "too big to be saved".

In the second group of banks with large SRISK, as calculated as a percentage of GDP, we find some of the largest European banks that are also in the top five for systemic risk in banks (Barclays, Royal Bank of Scotland, Credit Agricole, BNP Paribas, and Deutsche Bank). Their expected capital shortfall in case of a domestic crash represents approximately 6-7% of the domestic GDP. Bank of Ireland, which has already been bailed out during the Irish banking crisis, still has a very low market capitalization and is highly undercapitalized. Finally, some relatively smaller institutions (such as KBC Group in Belgium, DNB in Norway, Erste Group Bank in Austria, or the National Bank of Greece) have a capital shortfall of 3-5% of the GDP.

As the table also clearly demonstrates, certain countries have several financial institutions that are considered D-SIFIs. This finding clearly raises the issue of the capability of the domestic authorities to rescue two or more firms at the same time. In **Table 7**, we report the market capitalization and SRISK of the firms with the highest levels of systemic risk in proportion to the GDP of the country where they are located. Beginning with the U.S., the capital shortfall of the four riskiest banks (Bank of America, JP Morgan Chase, Citigroup, and MetLife) is 2.7% of the U.S. GDP. In Europe, the capital shortfall of the four riskiest banks (Deutsche Bank, Barclays, Crédit Agricole, and BNP Paribas) is 5.6% of the European GDP. These numbers are similar. However, the SRISK of the four riskiest U.S. banks only slightly exceeds their market capitalization (116%), whereas it is much larger (517%) for the four riskiest European banks. This observation confirms that the undercapitalization of banks in Europe is much more severe than in the U.S.

If we now consider the importance of large institutions relative to the size of their respective countries, we obtain a more worrisome picture. The capital shortfall of the four riskiest British banks (Barclays, Royal Bank of Scotland, HSBC, and Lloyds Banking) represents 22% of the U.K. GDP. UBS and Credit Suisse alone have a total capital shortfall equal to 26% of the Swiss GDP. For other countries, such as France, the Netherlands, or Sweden, the capital shortfall of the riskiest banks amounts to 16-18% of nominal GDP. We note that the two or four riskiest banks account for at least 80% of the total capital shortfall that European countries would suffer in case of a new 40% world market crash. In other words, the government might be unable to bail out such banks in the event of a new market crash.

5 Conclusion

In this paper, we investigate the systemic risk borne by European financial institutions over the recent period. For this purpose, we extend the approach developed by Brownlees and Engle (2010) for U.S. institutions. We develop an econometric approach designed to measure systemic risk of non-U.S. institutions, with the two following characteristics. First, there are several potential factors driving the dynamic of European financial institutions' returns. Second, the world return is likely to affect European firms' return instantaneously or with a one-day lag, due to the asynchronicity of the time zones. Our model combines a DCC model to estimate the dynamic of the beta parameters, univariate GARCH models to estimate the dynamic of the volatility of the error terms, and a t copula to estimate the dynamic of the dependence structure between the innovations.

We apply this methodology to the 196 largest European financial institutions and estimate their systemic risk over the 2000-2012 period. At the end of the study period

(August 30, 2012), the total exposure of these 196 firms was 2,000 billion euros. Banks and insurance companies bear approximately 80% and 20% of the systemic risk in Europe, respectively. Systemic risk is essentially unaffected by financial services and real estate firms. Over the recent period, the countries with the highest levels of systemic risk have been the U.K. and France, as these two countries have contributed to approximately 50% of the total exposure of European financial institutions. The five riskiest institutions over the recent period have been Deutsche Bank, Barclays, Crédit Agricole, BNP Paribas, and Royal Bank of Scotland, bearing almost 700 billion euros together, i.e., one third of the total expected shortfall in the case of a new financial crisis. Even after correcting for differences in accounting standards, the total systemic risk borne by European institutions is much larger than the one borne by U.S. institutions. More importantly, for certain countries, the cost for the taxpayer to rescue the riskiest domestic banks is so high that some banks might be considered "too big to be saved", such as UBS and Credit Suisse in Switzerland, ING Group in the Netherlands, Danske Bank in Denmark, or Nordea Bank in Sweden.

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Captions

Figure 1: Cumulative return by category. This figure displays the cumulative total return (including dividends) for the European market index and the indices reflecting the four industry groups between 1990 and 2012. The top panel focuses on banks and insurance companies, the lower panel on financial-services and real-estate firms.

Figure 2: Leverage and market capitalization by industry group. This figure displays the leverage (top panel) and the market capitalization (bottom panel) for the four industry groups between 2000 and 2012.

Figure 3: Dynamic of the betas in the International model and some Country models. This figure displays the dynamic of the betas in the International model and in some of the Country models (U.K., France, Germany).

Figure 4: Dynamic of the betas in some Firm models. This figure displays the dynamic of the betas in some Firm models.

Figure 5: LRMES and SRISK by industry group. This figure displays the LRMES and the systemic risk for the four industry groups between 2000 and 2012. The black line corresponds to a world shock, the blue dashed line to a European shock.

Figures 6 to 8: Market capitalization, Leverage, LRMES, and SRISK by country. These figures display the market capitalization, leverage, LRMES, and systemic risk measures for some countries, between 2000 and 2012. Reported countries are those with a systemic risk larger than 100 billion euros over the 2008-12 period. The black line corresponds to a world shock, the blue dashed line to a European shock.

Figures 9 to 10: Market capitalization, Leverage, LRMES, and SRISK by institution. These figures display the market capitalization, leverage, LRMES, and systemic risk measures for some institutions, between 2000 and 2012. The black line corresponds to a world shock, the blue dashed line to a European shock.

Table 1: Summary statistics on returns by industry group

	World	Europe	Banks	Insurance companies	Financial services	Real estate
Ann. return	3.87	2.97	1.85	1.65	3.13	1.51
Ann. volatility	18.34	16.26	22.07	22.41	14.35	12.78
Skewness	-0.04	-0.07	0.26	0.11	-0.33	-0.45
Kurtosis	9.07	7.57	14.34	11.38	10.81	9.69
Max draw down	-61.72	-65.24	-82.04	-79.05	-67.49	-77.65
5%-VaR (left)	-1.82	-1.66	-2.11	-2.14	-1.40	-1.24
5%-ES (left)	-2.78	-2.42	-3.41	-3.48	-2.25	-2.04
5%-VaR (right)	1.72	1.59	2.00	2.06	1.31	1.13
5%-ES (right)	2.63	2.34	3.30	3.36	1.99	1.80

This table provides summary statistics on the index return of European financial firms for the period from January 1990 until August 2012 (total return index, in euros). For each category, we report the average annualized return, annualized volatility, skewness, kurtosis, maximum draw down, 5% VaR and expected shortfall (ES) for the left and right sides of the distribution.

Table 2: Summary statistics on parameter estimates

	Banks	Insurance companies	Financial services	Real estate
Panel A: Parameter estimates (median)				
GARCH model (Volatility dynamic)				
ω	0.030	0.029	0.019	0.034
α	0.084	0.058	0.056	0.090
γ	0.023	0.005	0.017	0.026
β	0.895	0.929	0.920	0.911
Skewed t distribution				
ν	4.602	4.666	5.478	4.398
λ	0.049	0.041	0.019	0.014
Copula degree of freedom				
$\bar{\nu}$	16.061	16.485	16.862	18.435
Panel B: Conditional betas (median of means)				
$\beta^C_{i,t}$	0.930	0.734	0.625	0.337
$\beta^E_{i,t}$	0.051	0.299	0.258	0.189
$\beta^W_{i,t}$	-0.027	-0.006	0.027	0.032
$\beta^L_{i,t}$	0.027	0.111	0.123	0.113

This table provides summary statistics on parameter estimates and dynamics for all of the industry groups. Panel A reports the median of the parameter estimates across the institutions. Panel B reports the median of the average conditional beta parameters estimated in the cross-section of firms. The estimates correspond to the model estimated over the last ten years.

Table 3: Systemic risk and its components by industry group

	Banks	Insurance companies	Financial services	Real estate
Panel A: Entire sample				
Market capitalization	915.2	399.3	138.2	66.9
Leverage	18.8	16.2	4.0	2.2
LRMES wrt World	31.1	32.6	27.5	13.4
LRMES wrt Europe	36.6	38.5	32.0	15.9
SR wrt World	741.3	227.5	12.5	0.0
SR wrt Europe	774.6	242.6	12.9	0.0
Panel B: 2000-2007 period				
Market capitalization	913.6	446.4	133.2	58.0
Leverage	13.3	13.8	2.8	2.1
LRMES wrt World	27.5	29.9	25.2	11.1
LRMES wrt Europe	32.9	35.9	29.9	13.5
SR wrt World	353.4	173.8	5.8	0.0
SR wrt Europe	381.9	189.4	5.8	0.0
Panel C: 2008-2012 period				
Market capitalization	917.8	320.1	146.6	81.9
Leverage	28.0	20.3	5.9	2.5
LRMES wrt World	37.3	37.2	31.4	17.3
LRMES wrt Europe	42.9	42.7	35.6	19.9
SR wrt World	1394.6	317.9	23.8	0.1
SR wrt Europe	1436.2	332.2	24.8	0.1
Panel D: As of August 2012				
Market capitalization	857.6	326.3	156.2	98.0
Leverage	31.4	20.1	6.9	2.2
LRMES wrt World	37.5	38.6	32.4	21.2
LRMES wrt Europe	43.5	44.9	36.7	24.4
SR wrt World	1628.0	332.5	38.4	0.0
SR wrt Europe	1667.6	349.6	39.5	0.0

This table reports for all of the industry groups the median across firms of the mean over time of the market capitalization, leverage, the LRMES and the systemic risk measures (with respect to world and European shocks). LRMES is in % and systemic risk in billion euros. The mean is computed over the entire sample period, over the two subperiods 2000-07 and 2008-12, and for the last date of the sample.

Table 4: Systemic risk and its components by country

	U.K.	France	Germany	Italy	Switz.	Spain	Netherl.	Sweden
Panel A: Entire sample								
Market cap.	379.1	188.4	152.4	124.5	174.3	133.5	93.9	77.3
Leverage	14.2	23.1	25.3	16.0	15.6	11.5	17.6	13.3
LRMES wrt World	33.5	31.3	31.2	25.1	30.2	30.4	37.2	30.2
LRMES wrt Europe	39.1	37.2	36.6	29.8	35.8	36.6	43.5	35.3
SRISK wrt World	210.4	229.4	180.7	60.8	92.8	37.2	67.5	36.7
SRISK wrt Europe	221.2	238.0	186.2	64.3	99.7	42.0	70.7	39.1
Panel B: 2000-2007 period								
Market cap.	389.5	181.1	164.8	129.8	194.0	133.2	113.3	72.9
Leverage	9.3	16.1	20.3	10.5	13.3	8.3	11.9	11.3
LRMES wrt World	29.8	27.8	29.7	21.6	27.1	26.6	33.1	27.2
LRMES wrt Europe	35.5	33.7	35.8	26.0	32.9	32.6	39.4	31.9
SRISK wrt World	76.4	115.0	134.5	18.6	71.9	7.3	44.6	21.0
SRISK wrt Europe	84.9	122.9	140.3	21.1	79.3	10.5	48.2	23.0
Panel C: 2008-2012 period								
Market cap.	361.7	200.7	131.4	115.6	141.2	134.0	61.3	84.1
Leverage	22.3	34.7	33.9	25.4	19.5	16.9	27.3	16.3
LRMES wrt World	39.8	37.2	33.6	31.1	35.5	36.8	44.2	35.1
LRMES wrt Europe	45.2	43.3	38.1	36.1	40.8	43.3	50.4	40.7
SRISK wrt World	436.2	422.2	258.6	131.9	127.8	87.6	106.0	61.6
SRISK wrt Europe	450.7	431.8	263.7	137.0	134.0	95.0	108.7	64.6
Panel D: As of August 2012								
Market cap.	396.2	167.0	129.0	74.1	131.8	110.2	59.4	107.9
Leverage	23.3	40.8	36.0	36.4	21.5	21.6	26.6	14.7
LRMES wrt World	37.6	38.6	33.4	35.9	32.5	44.1	44.7	35.9
LRMES wrt Europe	42.6	45.7	38.9	41.9	37.1	52.3	51.6	41.3
SRISK wrt World	527.2	465.1	283.8	166.7	144.2	126.2	108.4	70.3
SRISK wrt Europe	542.4	474.1	290.3	170.7	149.4	134.2	111.4	74.2

This table reports for some countries the median across firms of the mean over time of the market capitalization, leverage, the LRMES and the systemic risk measures (with respect to world and European shocks). Reported countries are those with a systemic risk larger than 60 billion euros over the 2008-12 period. LRMES is in % and systemic risk in billion euros. The mean is computed over the entire sample period, over the two subperiods 2000-07 and 2008-12, and for the last date of the sample.

Table 5: Ranking of G-SIFIs (as of August 30, 2012)

Rk	Institution	Country	World shock SRISK (bln eur)	World shock LRMES (%)	European shock SRISK (bln eur)	European shock LRMES (%)	Leve-rage	Market cap. (bln eur)
1	Deutsche Bank	Germany	161.5	43.4	162.0	45.6	84.8	26.1
2	Barclays	UK	141.2	48.2	141.9	50.7	69.4	28.3
3	Crédit Agricole	France	134.0	47.3	134.5	51.7	151.6	11.6
4	BNP Paribas	France	128.6	46.1	131.0	52.3	44.3	43.3
5	RBS	UK	125.4	39.7	126.2	44.4	96.8	17.6
6	Société Générale	France	87.9	50.3	88.7	55.5	73.6	16.4
7	ING Group	Netherl.	85.3	56.9	86.4	62.3	51.7	23.3
8	HSBC	UK	77.8	31.8	76.5	30.8	16.5	126.2
9	Lloyds Banking	UK	72.0	33.5	73.2	37.7	39.1	29.5
10	UBS	Switz.	71.5	40.8	72.7	44.6	34.0	34.1
11	Banco Santander	Spain	67.3	46.4	73.1	57.7	22.2	56.0
12	Unicredito	Italy	61.0	39.9	61.9	45.1	49.8	18.2
13	Credit Suisse	Switz.	54.6	36.7	55.9	43.3	42.0	20.3
14	Commerzbank	Germany	47.4	37.2	47.5	39.7	88.9	7.3
15	AXA	France	43.7	52.9	45.3	59.0	26.6	27.1
16	Nordea Bank	Sweden	38.2	40.6	38.4	41.5	23.9	29.7
17	Intesa Sanpaolo	Italy	37.7	39.3	38.9	46.0	32.3	19.4
18	Natixis	France	34.7	30.7	34.9	34.4	73.6	6.7
19	Banco Bilbao	Spain	30.4	49.0	33.1	58.0	18.5	32.7
20	Danske Bank	Denmark	27.3	28.6	27.6	31.4	35.7	12.9
21	Legal & General	UK	26.7	38.6	27.0	42.2	43.1	9.5
22	Allianz	Germany	26.6	39.5	26.6	39.4	16.4	39.6
23	Aegon	Netherl.	23.1	54.5	23.4	58.6	42.7	7.9
24	Aviva	U.K.	22.8	46.9	22.9	47.2	30.9	12.0
25	Generali	Italy	22.2	35.0	23.5	43.0	24.2	17.7

This table reports the ranking of European financial firms by systemic risk as of August 30, 2012. For each firm, we report the name, country, SRISK (in billion euros), LRMES (in %), leverage, and market capitalization (in billion euros). We report SRISK and LRMES for both world and European shocks.

Table 6: Ranking of D-SIFIs (as of August 30, 2012)

Rk	Institution	Country	SRISK (bln eur)	World shock SRISK (% GDP)	LRMES (%)	Leverage	Market cap. (bln eur)
1	UBS	Switz.	71.5	14.6	40.8	73.2	34.1
2	ING Group	Netherl.	85.3	13.3	56.9	87.6	23.3
3	Credit Suisse	Switz.	54.6	11.2	36.7	55.6	20.3
4	Danske Bank	Denmark	27.3	10.7	28.6	27.6	12.9
5	Nordea Bank	Sweden	38.2	9.2	40.6	40.0	29.7
6	Barclays	U.K.	141.2	7.6	48.2	142.8	28.3
7	Royal Bk of Scotland	U.K.	125.4	6.7	39.7	126.4	17.6
8	Banco Santander	Spain	67.3	5.9	46.4	72.3	56.0
9	Crédit Agricole	France	134.0	6.3	47.3	134.7	11.6
10	Bank of Ireland	Ireland	10.2	6.1	35.5	10.3	2.7
11	BNP Paribas	France	128.6	6.0	46.1	132.3	43.3
12	Deutsche Bank	Germany	161.5	5.9	43.4	163.2	26.1
13	KBC Group	Belgium	18.1	4.6	43.4	18.5	6.2
14	DNB	Norway	14.2	3.8	30.7	14.9	14.9
15	HSBC	U.K.	77.8	4.2	31.8	83.4	126.2
16	Société Générale	France	87.9	4.1	50.3	89.1	16.4
17	Erste Group Bank	Austria	12.4	3.9	34.2	12.7	6.3
18	Lloyds Banking	U.K.	72.0	3.9	33.5	73.3	29.5
19	Unicredito	Italy	61.0	3.6	39.9	61.9	18.2
20	Aegon	Netherl.	23.1	3.6	54.5	23.8	7.9
21	National Bank of Greece	Greece	7.6	3.3	31.3	7.6	1.3
22	SEB	Sweden	12.9	3.1	37.7	13.5	13.2
23	Svenska Handelsbanken	Sweden	11.5	2.8	31.0	12.2	17.1
24	Banco Bilbao	Spain	30.4	2.7	49.0	32.9	32.7
25	Banco Espirito Santo	Portugal	4.8	2.6	24.9	4.9	2.2

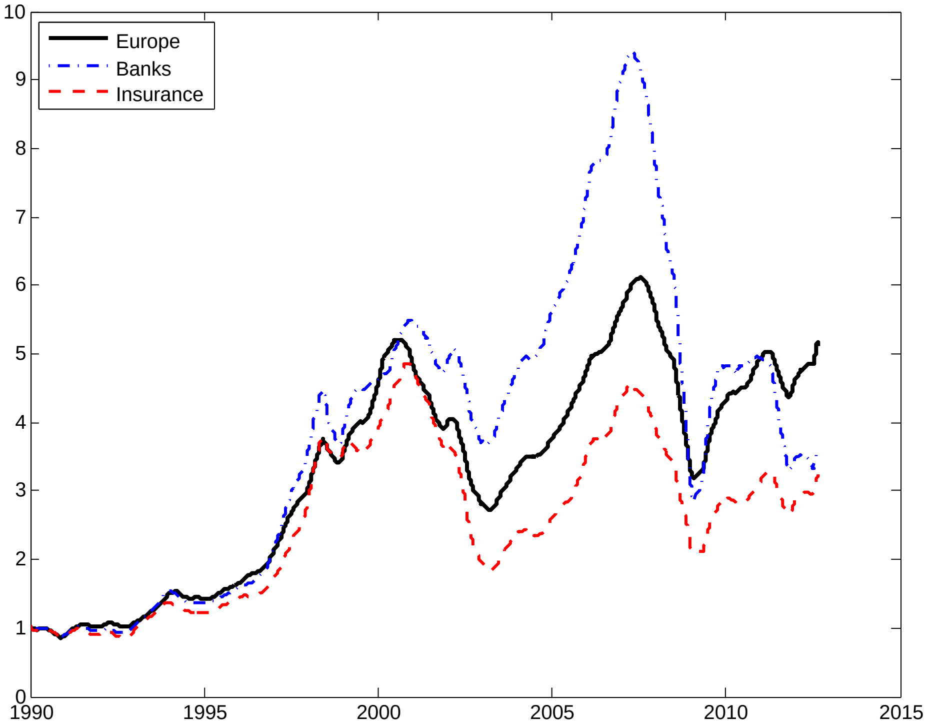
This table reports the ranking of European financial firms by SRISK as of August 30, 2012 in percentage of domestic nominal GDP. For each firm, we report the name, country, SRISK (in billion euros and % GDP), LRMES (in %), leverage, and market capitalization (in billion euros). We report SRISK and LRMES for a world shock. We take the last annual GDP estimate (2011).

Table 7: Importance of D-SIFIs in proportion to country-wide aggregate indicators

	x	Market cap. (% GDP)	SRISK (% total SRISK)	SRISK (% GDP)	SRISK (% Mkt cap.)
U.S.	4	2.3	57.6	2.7	116.0
Euro area	4	1.1	28.2	5.6	517.2
U.K.	4	10.8	79.0	22.3	206.5
France	4	4.6	84.8	18.5	400.4
Germany	4	3.0	88.1	9.1	308.5
Italy	4	3.4	82.4	8.1	237.2
Switzerland	2	11.1	85.9	25.8	232.1
Spain	4	8.5	92.0	10.1	119.1
Netherlands	2	4.9	100.0	16.8	347.1
Sweden	4	17.7	100.0	17.0	96.1

This table reports the market capitalization and systemic risk of the x largest firms as of August 30, 2012 as a fraction of country-wide aggregate indicators (nominal GDP, total SRISK, and market capitalization).

Figure 1: Cumulative return by category



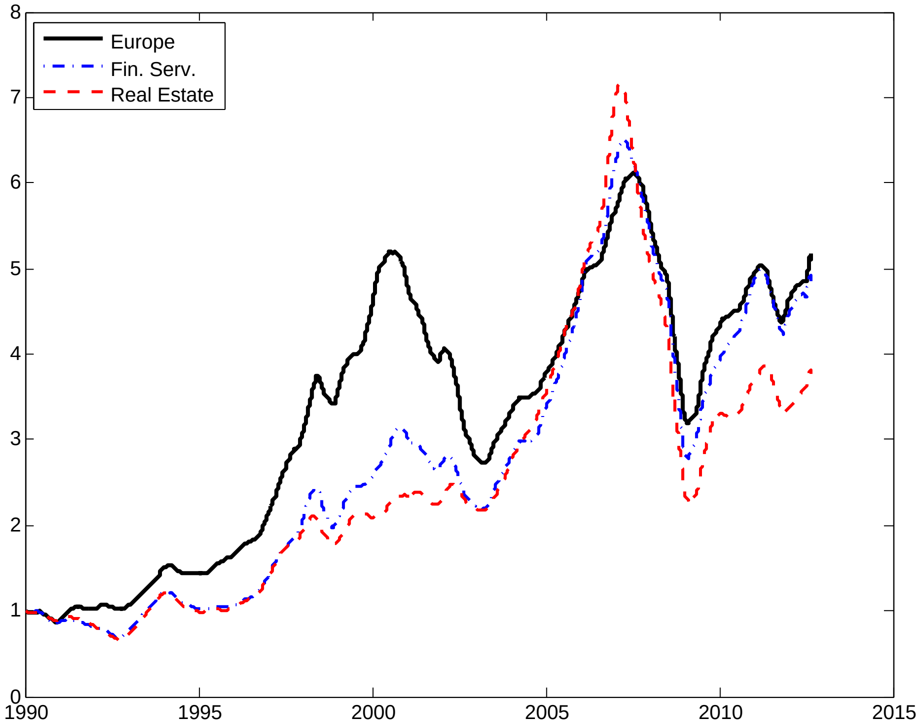


Figure 2: Leverage and market capitalization by industry group

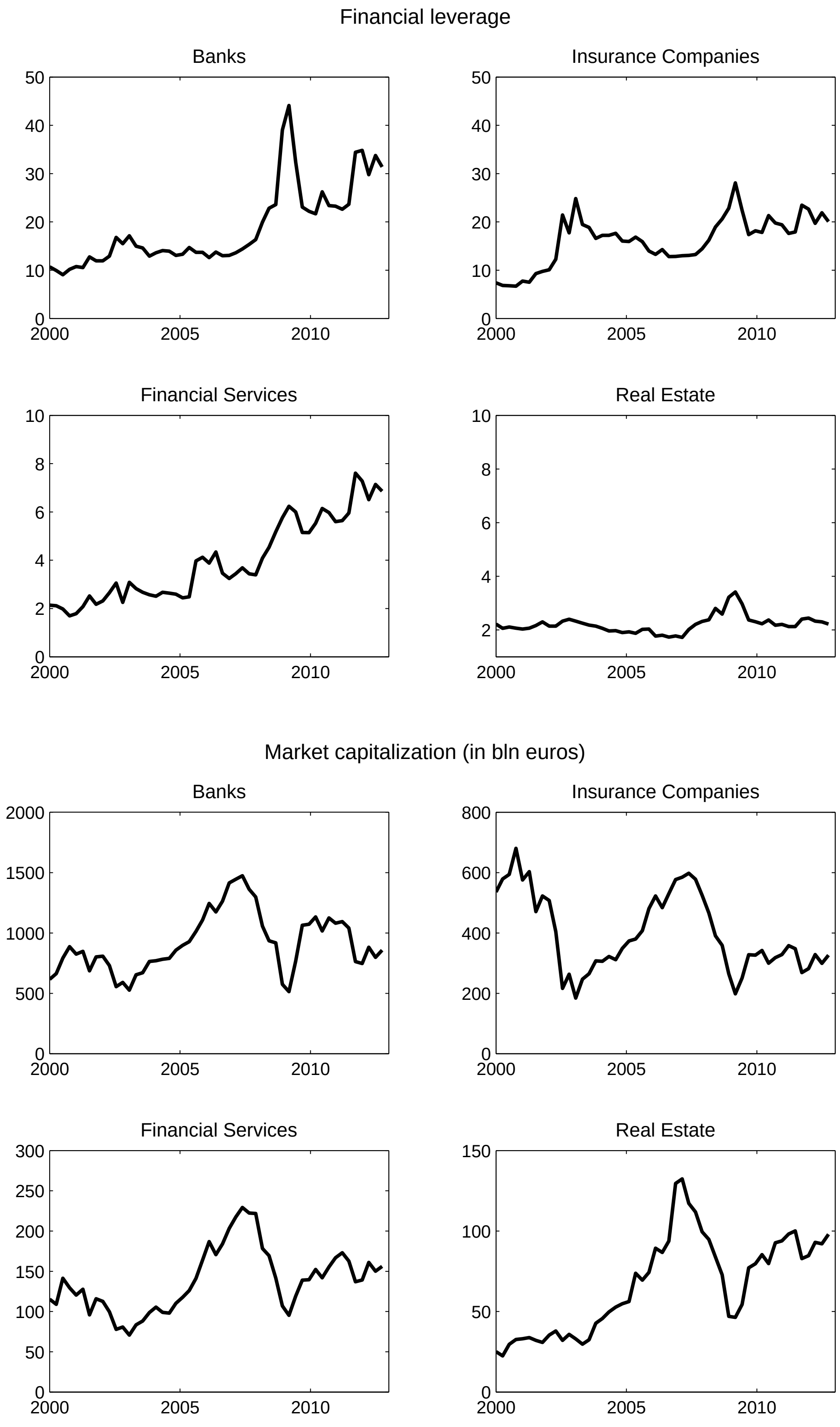


Figure 3: Dynamic of the betas in the International model and some Country models

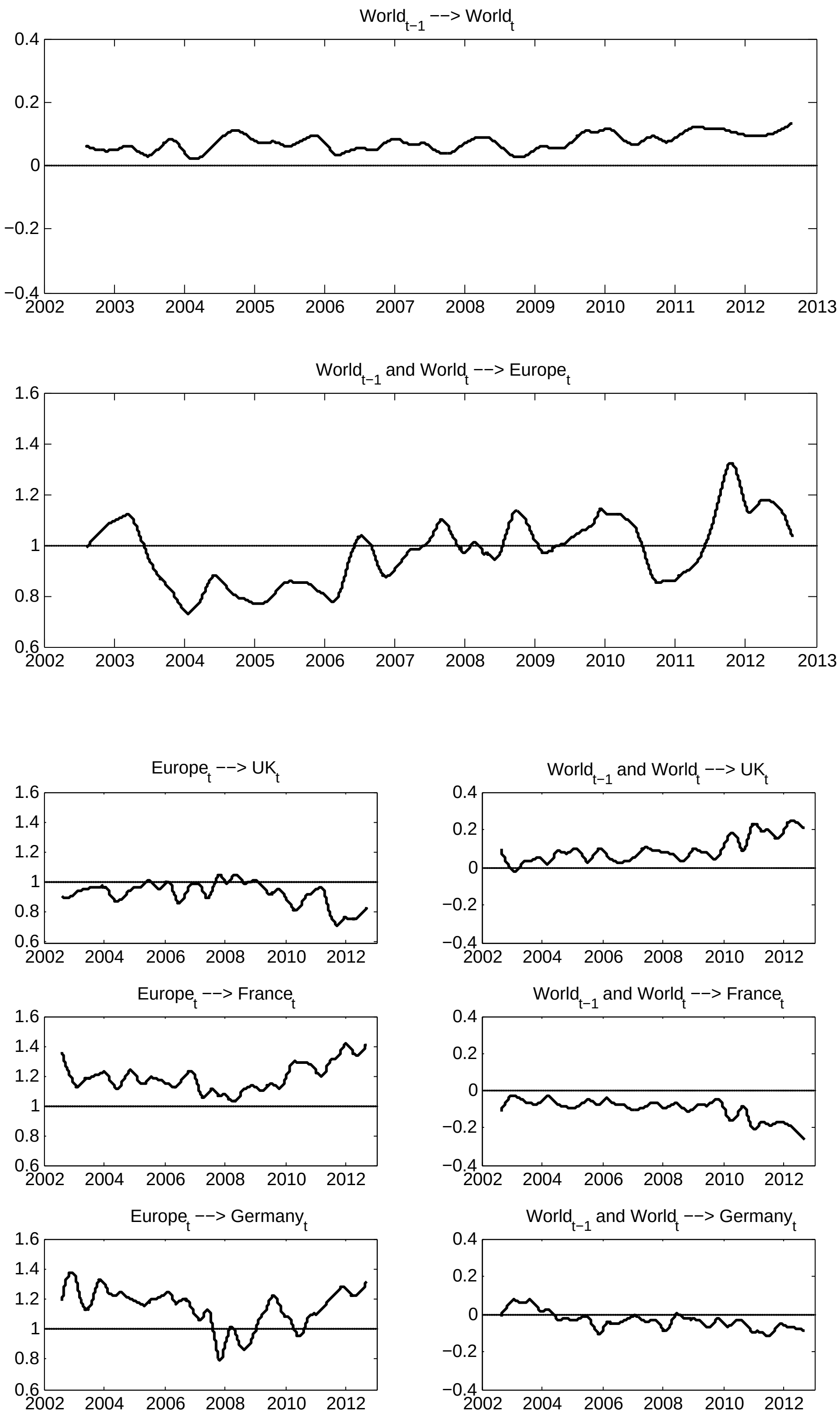


Figure 4: Dynamic of the betas in some Firm models

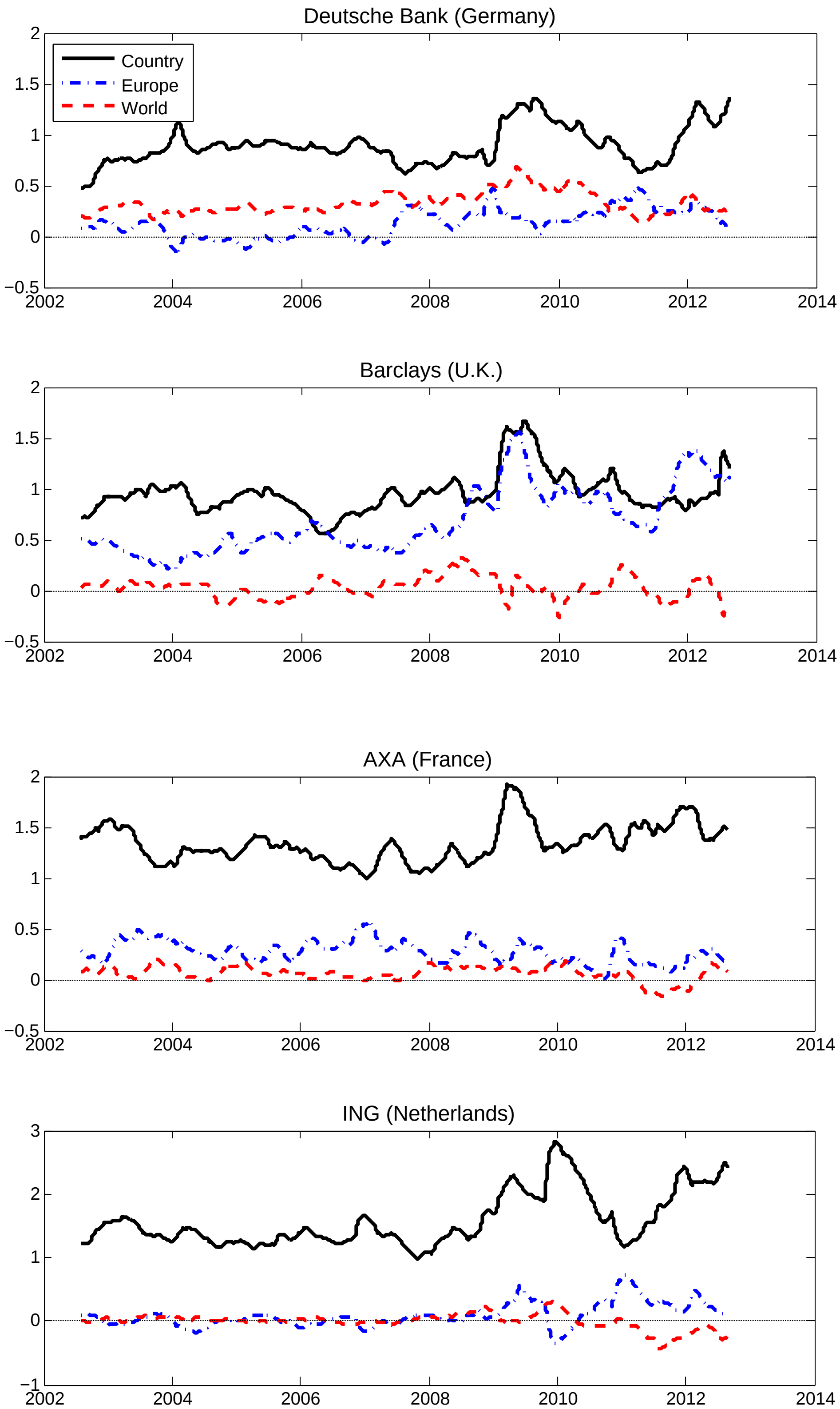


Figure 5: LRMES and SRISK by industry group

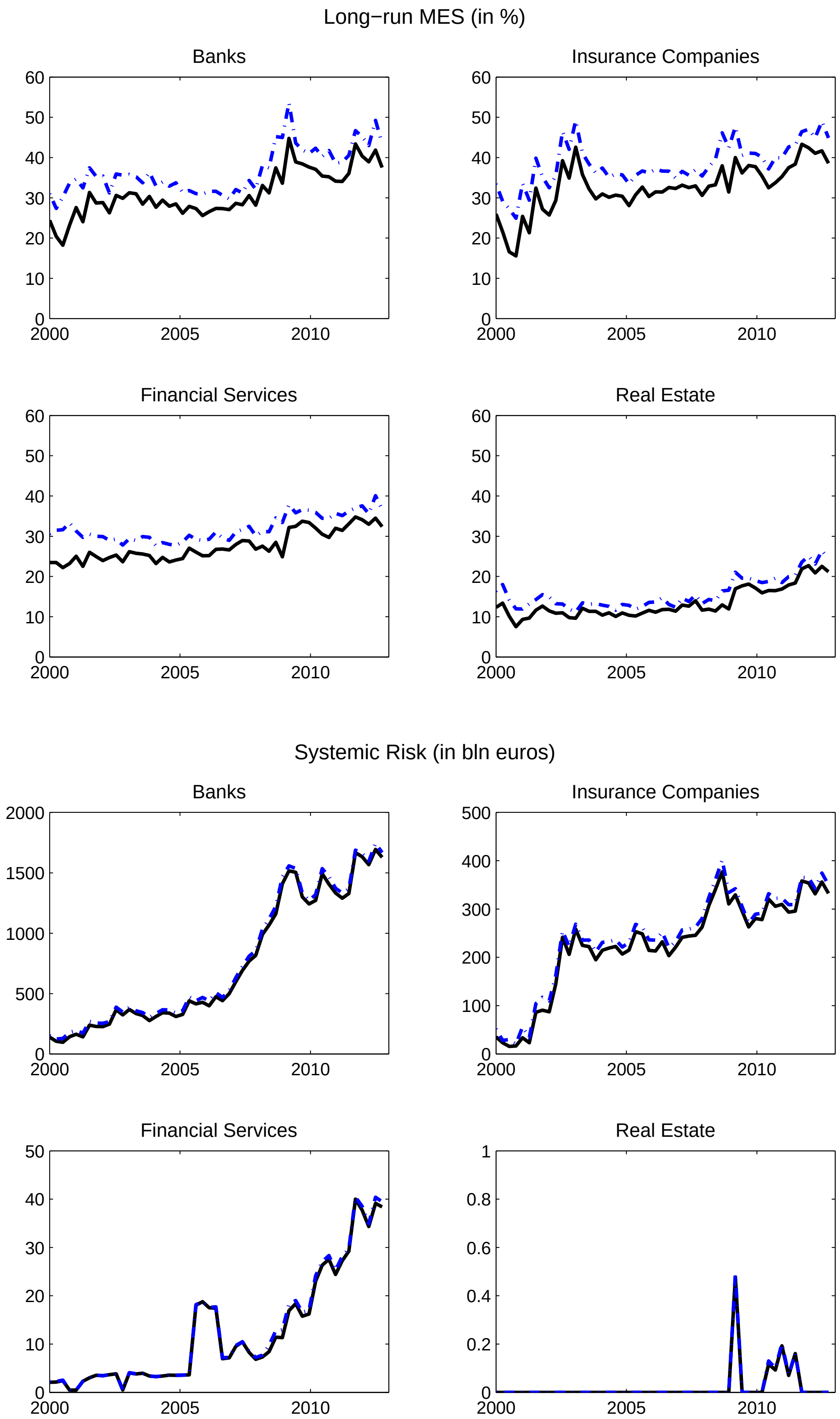


Figure 6: Market capitalization, Leverage, LRMES, and SRISK by country

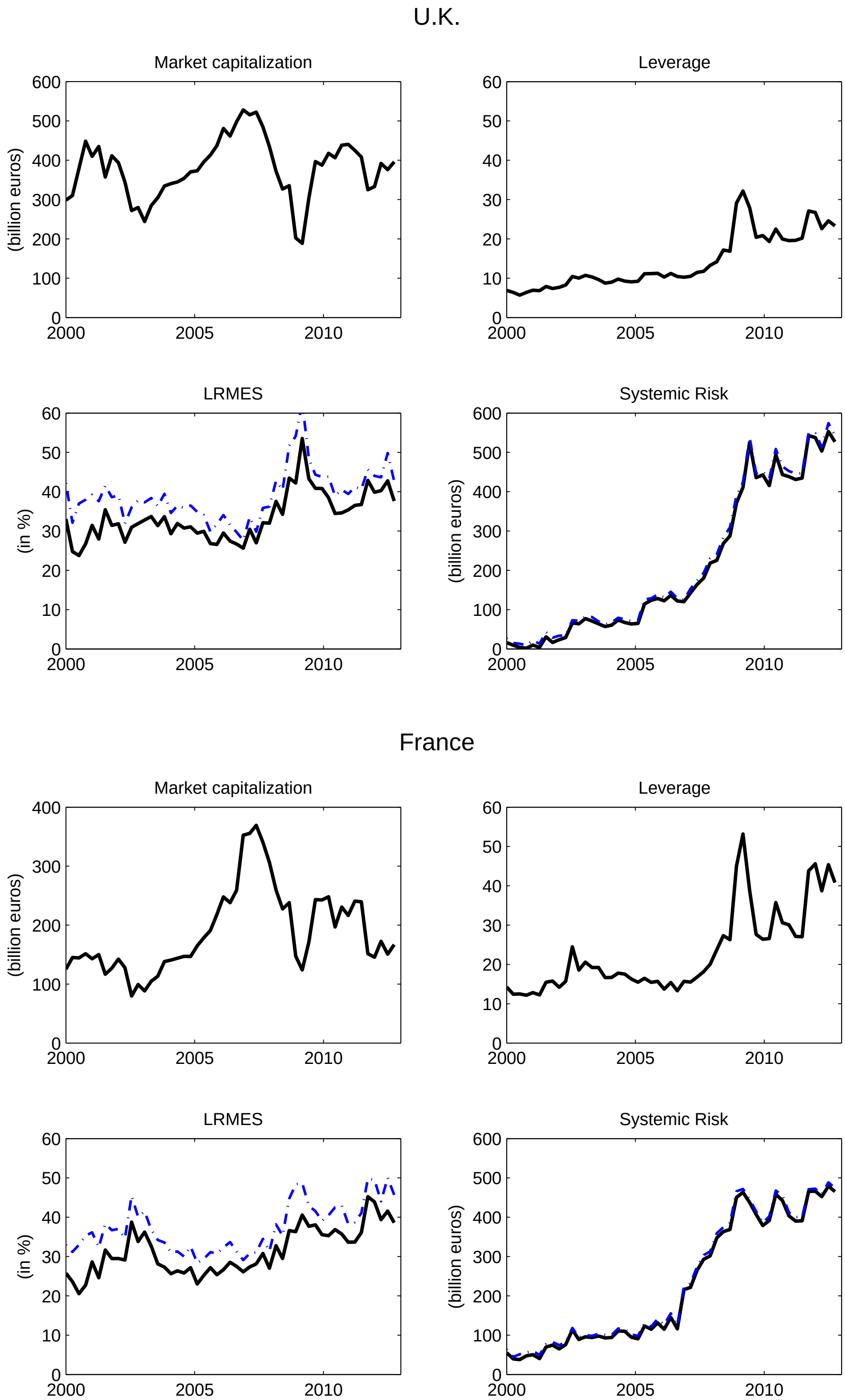


Figure 7: Market capitalization, Leverage, LRMES, and SRISK by country (cont'd)

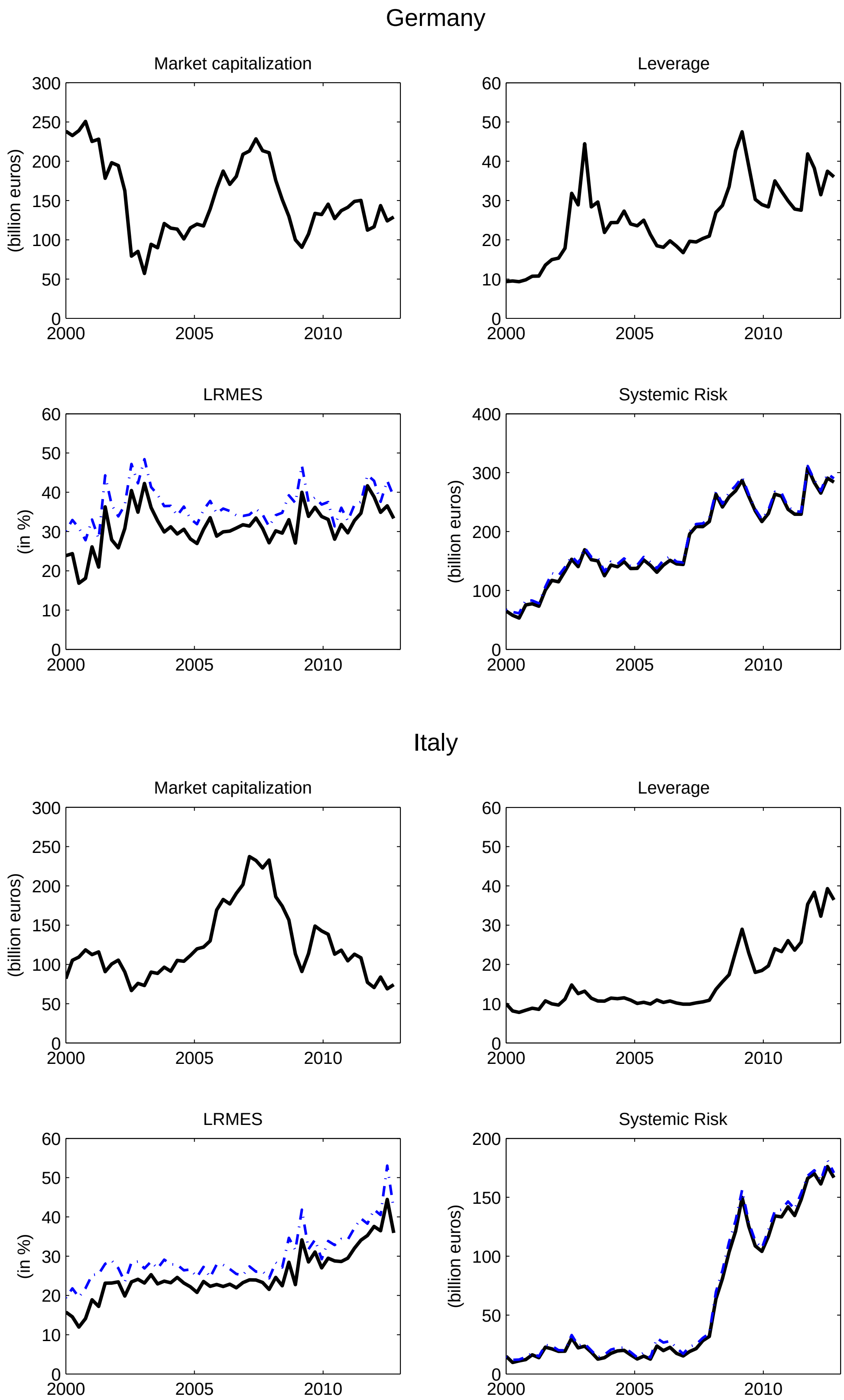


Figure 8: Market capitalization, Leverage, LRMES, and SRISK by country (cont'd)

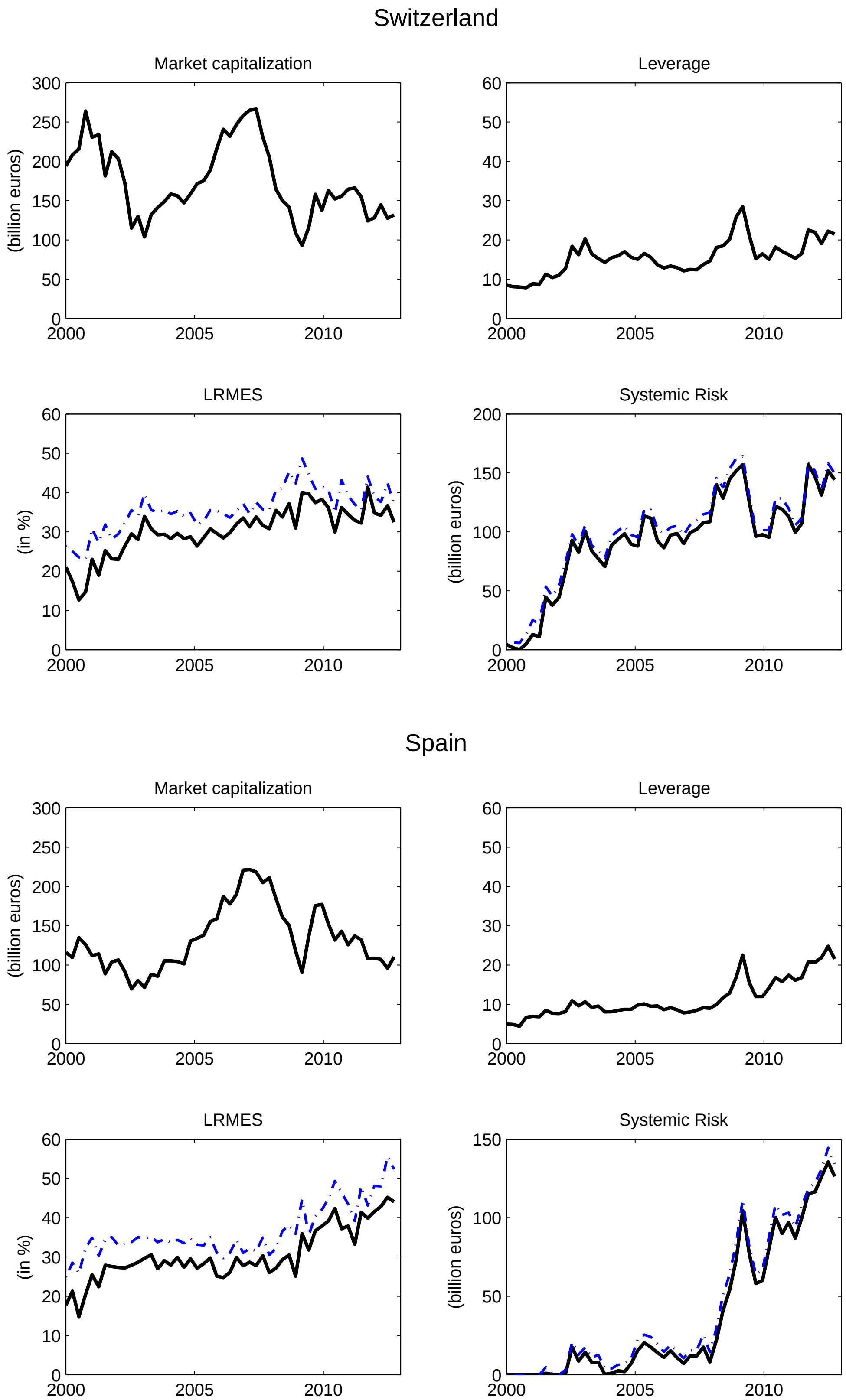


Figure 9: Market capitalization, Leverage, LRMES, and SRISK by institution

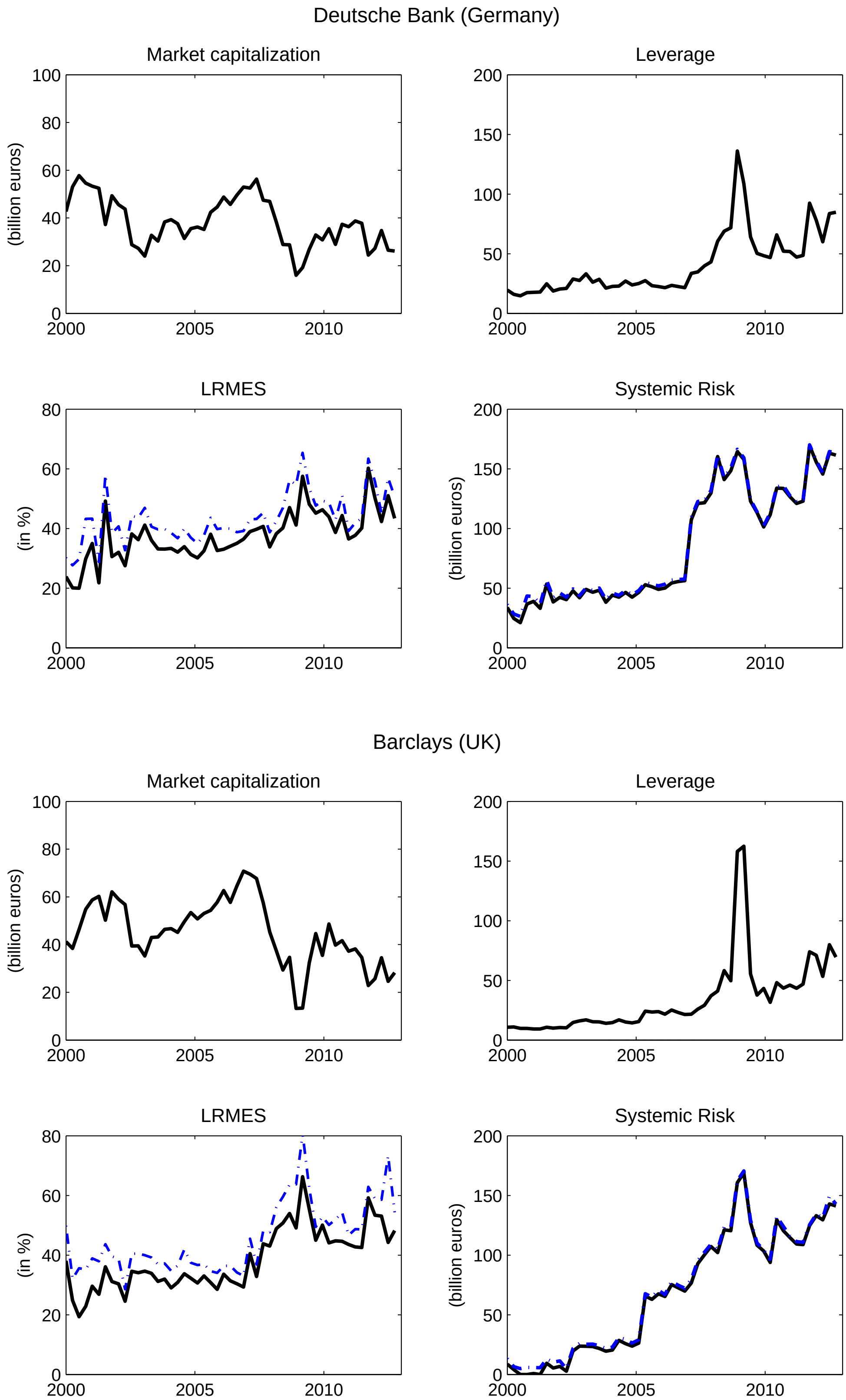
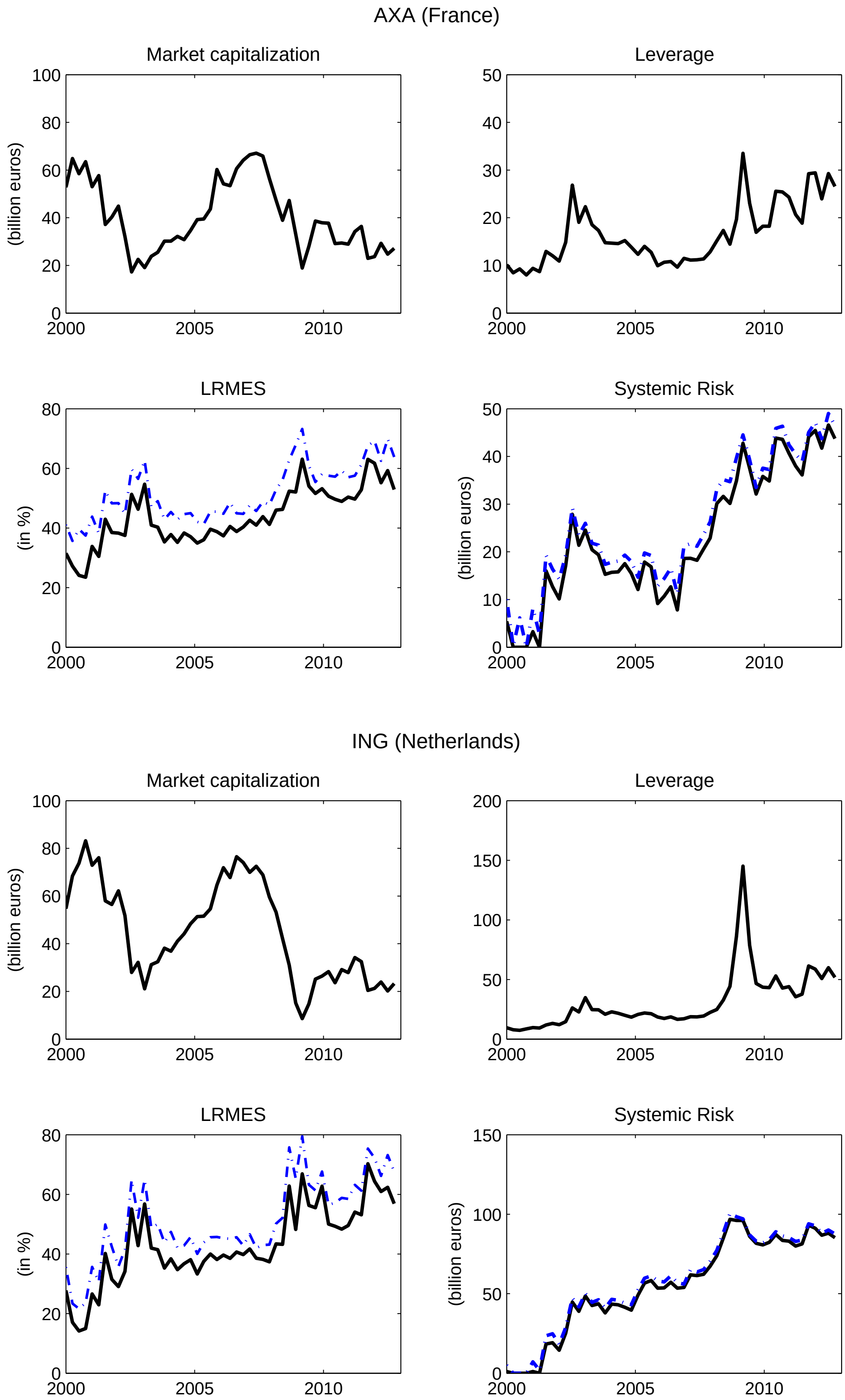


Figure 10: Market capitalization, Leverage, LRMES, and SRISK by institution (cont'd)



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